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FATIGUE OF FOUR STAINLESS STEELS, FOUR TITANIUM ALLOYS, AND TWO ALUMINUM ALLOYS BEFORE AND AFTER EXPOSURE TO ELEVATED TEMPERATURES FOR UP TO THREE YEARS

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16. Abstract

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SUMMARY

Tensile specimens and unnotched, notched, spotwelded, and fusion-welded fatigue specimens from sheets of four stainless steels, four titanium alloys, and two aluminum alloys were tested at room temperature before and after exposure to elevated temperatures for up to 3 years. The steels and titanium alloys were exposed at 560 K (550° F) and the aluminum alloys were exposed at 390 K and 420 K (250° F and 300° F). Fatigue data covering a range of fatigue lives from 10^3 to 10^7 cycles were obtained before and after 3 years of exposure. The fatigue strengths after exposure were essentially the same as those before exposure.

INTRODUCTION

During most of the flying hours of supersonic transport airplanes, much of the structure will be at elevated temperatures. The long thermal exposure is potentially detrimental to the load-carrying capacity of structural materials. Despite the adverse operational environment, the structural materials for supersonic airplanes must retain their essential mechanical and physical properties throughout the designated service life of the airplane. Therefore, information is needed about the effects of long exposure to elevated temperature on candidate structural materials. Accordingly, the effects of such exposure on the properties of a number of materials have been investigated. (See refs. 1 to 5.) In reference 1, the effects of elevated-temperature exposure on room-temperature fatigue life were reported for several stainless steels and titanium alloys after exposures of up to 8800 hours at 560 K (550° F). The present report extends the results for those materials to 26 300 hours (3 years), includes results from reference 1 pertinent to the elevated-temperature exposure, and presents results for three additional materials (aluminum alloys 2024T-81 and RR 58 (a British alloy) and duplex annealed Ti-8Al-1Mo-1V, titanium alloy). The investigation encompassed approximately 3000 tests.

SYMBOLS

The data of this paper were obtained in the U.S. Customary Units but are presented in both the International System of Units and U.S. Customary Units. Factors relating these two systems are given in reference 6; those pertinent to the results herein are presented in appendix A.

e	permanent tensile elongation, percent in 50-mm (2-inch) gage length
K_T	theoretical stress concentration factor
N	life of fatigue specimen, cycles
S	stress, MN/m^2 (ksi)
S_{max}	nominal maximum stress during a fatigue stress cycle, MN/m^2 (ksi)
S_{mean}	nominal mean stress during a fatigue stress cycle, MN/m^2 (ksi)
S_u	static tensile ultimate strength, MN/m^2 (ksi)
S_y	static tensile yield stress at 0.2-percent offset, MN/m^2 (ksi)

Abbreviations:

An	annealed
CR	cold rolled
CRT	cold rolled and tempered
DA	double aged
DAn	duplex annealed
STA	solution treated and aged
TH	transformation and precipitation hardened

SPECIMENS

Sheets of four stainless steels, four titanium alloys, and two aluminum alloys were used in the manufacture of specimens. All sheets of each material were from a single lot. The heat-treatment conditions and sheet thicknesses of the materials are given in the following table:

Alloy	Treatment	Thickness, mm	Thickness, in.
	Stainless steels		
PH 15-7 Mo	Transformation and precipitation hardened (TH 1050)	0.64	0.025
AM 350	Cold rolled and tempered (CRT)	.64	.025
AM 350	Double aged (DA)	.64	.025
AISI 301	Cold rolled (CR)	.64	.025
	Titanium alloys		
Ti-6Al-4V	Annealed (An)	1.02	0.040
Ti-4Al-3Mo-1V	Solution treated and aged (STA)	1.14	.045
Ti-8Al-1Mo-1V	Annealed (An)	1.02	.040
Ti-8Al-1Mo-1V	Duplex annealed (DAn)	1.27	.050
	Aluminum alloys		
Clad RR 58	Solution treated and aged (British alloy similar to U.S. alloy 2618)	1.60	0.063
Clad 2024	Solution treated and aged (T81)	1.60	.063

The chemical compositions and heat-treatment details for these materials are given in appendix B.

Four types of fatigue specimens, as shown in figure 1, were fabricated: unnotched specimens $(K_T = 1)$ to reveal changes in fatigue behavior of the material; edge-notched specimens $(K_T = 4)$ to represent stress raisers; and spotwelded and fusion-welded specimens to represent two kinds of welded joints. (The aluminum alloys were evaluated

in only the unnotched and notched configurations.) Standard tensile specimens with test sections 1.27 cm (0.5 in.) wide and 6.35 cm (2.5 in.) long were used to determine the tensile properties of the materials. Sheet materials and specimens were handled carefully to protect their surfaces against scratches or other types of marring. Details of specimen fabrication and handling are presented in appendix B.

PROCEDURE

Tensile and fatigue properties were determined for each material and specimen configuration before exposure. A large number of fatigue and tensile specimens were suspended without load in ovens for exposure to elevated temperature. A single standard tensile specimen was included with each group of 10 fatigue specimens to provide a check on possible deterioration of static strength. The temperatures of the ovens were maintained within ±5 K (±10 F$^{\circ}$) of the desired temperatures and were monitored by thermocouples welded to sample specimens. The titanium alloys and stainless steels were exposed at 560 K (550° F) which was considered to be a representative structural temperature for flight at about Mach 3. The aluminum alloys were exposed at 390 K and 420 K (250° F and 300° F) which are representative temperatures for flight at about Mach 2.

After intermediate periods of 3, 6, 12, and 24 months, a few specimens of each type were removed from the ovens and tested at room temperature to detect changes in fatigue and tensile properties from those established prior to exposure. Fatigue tests after the intermediate periods of exposure were conducted at a single level of maximum stress determined for each combination of specimen configuration and material. The maximum stress levels were chosen above the fatigue limit of unexposed specimens but at a level which would provide reasonably long fatigue lives. After exposures of about 3 years, fatigue data over a range of lives from 10^3 to 10^7 cycles were obtained for most of the materials for comparison with the S-N curves for unexposed material.

Fatigue tests were conducted in axial-load, subresonant-type, fatigue-testing machines, described in reference 1, which operated at 30 Hz (1800 cpm). The machines were calibrated periodically and a loading accuracy of ±44 N (±10 lbf) was maintained. All materials of the same class were tested at the same value of mean stress: stainless steels, 280 MN/m^2 (40 ksi); titanium alloys, 170 MN/m^2 (25 ksi); and aluminum alloys, 90 MN/m^2 (13 ksi). The mean stresses are about one-fifth of the respective ultimate tensile strengths. That ratio was chosen to approximate the ratio of mean stress to ultimate tensile strength that prevails in contemporary subsonic aluminum-alloy transport airplanes.

The effect of the elevated-temperature exposure on the static strength of stainless-steel and titanium-alloy fatigue specimens was determined by room-temperature tensile tests of each type of fatigue specimen before and after 3 years at 560 K (550° F).

RESULTS AND DISCUSSION

Tensile Properties

The tensile properties at room temperature determined from tensile tests of all the materials for exposures of 0 to 3 years are given in table I and are plotted in figure 2. These data show that among the stainless steels and titanium alloys, the net changes in tensile properties after the maximum exposures did not exceed 10 percent except for the average elongation of AISI 301 which decreased by 25 percent (from 0.04 to 0.03). References 2 and 3 confirmed these trends but indicated larger changes in the ultimate tensile strength of AISI 301 than did the present investigation; reference 3 reported an increase in ultimate tensile strength of AISI 301 of 15 percent, a loss of elongation of 50 percent, and attributed the changes to metallurgical instability.

Consistent with the results of reference 4, changes in the tensile properties of the aluminum alloys after exposure at 390 K (250° F) were generally small; at 420 K (300° F) the tensile strengths were reduced somewhat more than at 390 K (250° F). The maximum length of exposure at 420 K (300° F) was about 1 year for the RR58 and about 2 years for the 2024 because the heating oven malfunctioned and forced termination of this part of the investigation.

Based on these observations, the tensile properties of these materials generally were not affected to an extent prohibitive of use in structures heated to the temperatures investigated. However, these results and the results of references 3 and 4 indicate that the effects of elevated temperature exposure should be carefully considered in the use of AISI 301 at 560 K (550° F) and the two aluminum alloys at 420 K (300° F).

Fatigue Data

Pre-exposure fatigue tests.- The results of pre-exposure fatigue tests are presented in table II and figure 3. Generally, the data for notched and spotwelded specimens were less widely scattered than the data for unnotched or fusion-welded specimens, as would normally be expected. (See, for example, ref. 7.) However, an unusually high degree of scatter was observed in the results for unnotched specimens of AISI 301 as shown in figure 3(d). The photomicrographs in references 1 and 3, from the same lot of material, show large stringer-like inclusions up to 0.015 cm (0.006 in.) long. The large scatter resulting from tests of AISI 301 should probably not be considered as typical because other lots of the material might contain fewer large inclusions.

Fatigue tests after exposure.- The results of fatigue tests after elevated-temperature exposure for 26 300 hours are given in table III; these data are plotted in figure 3 (solid symbols) along with the pre-exposure data (open symbols) so that the effect of the exposure may be readily assessed. Generally, the elevated-temperature exposure caused minimal changes in fatigue strength. However, AISI 301 unnotched specimens exhibited somewhat greater scatter after exposure than before. This effect could be attributed to a partial phase transformation that was reported in reference 3.

The fatigue lives determined after the intermediate exposure periods are given in table IV. These data are indicated in figure 3 by a scatterband that extends from the minimum to the maximum fatigue lives obtained after any exposure period. The scatter in results for a given material and specimen configuration generally was affected by the proximity of the maximum stress to the fatigue limit; maximum stresses near the fatigue limit resulted in wider scatter than maximum stresses further from the fatigue limit, as would normally be expected.

Failure location in welded fatigue specimens.- As shown in figure 4, fatigue cracks in fusion-welded specimens developed in and propagated along the heat-affected zone and fatigue cracks in spotwelded specimens developed at boundaries of the heat-affected zones surrounding the spotwelds. In the latter case, cracks thus formed propagated approximately one-third of the way around the perimeter of the heat-affected zone before joining with a similar crack at an adjacent weld. Thus, the propagation of cracks in the spotwelded specimens produced a scalloped fracture surface (fig. 4).

Static Strengths of Fatigue Specimens

The static tensile strengths of fatigue specimens of the steels and titanium alloys were determined before and after exposure as another means of assessing the effect of long exposures to elevated temperature. The strengths and ratios of the strengths before and after exposure are given in table V. The strengths were determined by dividing the maximum load from the static test by the net cross-sectional area of the specimen for the unnotched, notched, and fusion-welded specimens. For spotwelded specimens, the maximum load was divided by the cross-sectional area of the specimen away from the doubler. Generally, all materials and configurations exhibited no significant changes in tensile strengths.

CONCLUDING REMARKS

Fatigue and tensile specimens of four stainless steels, four titanium alloys, and two aluminum alloys were exposed to elevated temperatures for periods up to 3 years. At intervals the specimens were tested under axial load at room temperature to determine

their fatigue and tensile properties. Fatigue data covering a range of fatigue lives from 10^3 to 10^7 cycles were obtained before and after 3 years of exposure for most materials. The fatigue strengths and tensile properties after exposure were not significantly different from those before exposure.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., December 7, 1970.

APPENDIX A

CONVERSION OF U.S. CUSTOMARY UNITS TO SI UNITS

Factors required for converting the units used herein to the International System of Units (SI) are given in the following table:

Physical quantity	U.S. Customary Unit	Conversion factor (*)	SI Unit (**)
Force	pound (lbf)	4.448	newton (N)
Frequency	cycle per second (cps)	1.0	hertz (Hz)
Length	inch (in.) feet (ft)	0.0254 0.3048	meter (m) meter (m)
Stress	ksi = 1000 lbf/in^2	6.895×10^6	$newton/meter^2$ (N/m^2)
Temperature	$^{\circ}F$	$\frac{5}{9}(^{\circ}F + 459.7)$	kelvin (K)

*Multiply a value given in U.S. Customary Units by the conversion factor to obtain the equivalent value in SI Units, or apply the conversion formula.

**Prefixes to indicate multiples of SI Units are as follows:

Prefix	Multiple
micro (μ)	10^{-6}
milli (m)	10^{-3}
centi (c)	10^{-2}
kilo (k)	10^{3}
mega (M)	10^{6}

APPENDIX B

SPECIMENS AND MATERIALS

This appendix presents details of specimen fabrication, handling and treatment of materials, chemical composition, and heat treatments.

Specimen Fabrication

Unnotched specimens.- The 19-cm $\left(7\frac{1}{2}\text{-in.}\right)$ radius of the unnotched specimens (fig. 1) was cut in a lathe by mounting the blanks on the headstock in stacks of 6 to 12 at one time. Machining speed was 14 revolutions per minute or 28 cm (11 in.) per second. Each of the final two passes removed 25 μm (0.001 in.) of material and that procedure produced a finish of 1.6 μm (64 μin.) root mean square. Although machining techniques were chosen to minimize burrs, they could not be eliminated entirely. Therefore, the corners in the fatigue critical areas were chamfered to remove the burred material. The beveling tool was a block of wood having about a 19-cm $\left(7\frac{1}{2}\text{- in.}\right)$ radius with number 600 emery paper fixed to the circumference. The bevel was produced by hand with light longitudinal strokes. The resulting bevel face was approximately 0.10 mm (0.004 in.) wide at a 45° angle to the surface of the specimen.

Notched specimens.- The notch radii of the notched specimens (fig. 1) were formed by drilling successively larger holes. The final three drill sizes were 2.80 mm, 2.87 mm, and 2.94 mm (0.110 in., 0.113 in., and 0.116 in.) in diameter. The first two drills were guided by a bushing, but the last drill was free. The blanks were drilled in stacks of 10 against a thick plate of cold-rolled steel. Only new drills were used and each was discarded after drilling the stack once. Drilling speed was 925 revolutions per minute and 71 μm/s (11/64 in./min) feed with the drills lubricated continuously. The notches were completed by slotting from the edge with a 2.38-mm-wide (3/32-in.) milling tool. Burrs produced by the drilling operation were removed by chamfering the edges of the hole at a 45° angle. The beveling tool was a cone-shaped piece of rubber-abrasive composite chucked in a drill press which ran at 3000 revolutions per minute. The procedure required the specimens to be lightly touched against the cone to produce a chamfer 0.10 mm (0.004 in.) wide.

Spot-welded specimens.- The four components of the spot-welded specimens (fig. 1) were machined to size prior to welding. Edge finish was 1.6 μm (64 μin.) root mean square and the corners were broken with a fine file.

Fusion-welded specimens.- The two components of the fusion-welded specimens (fig. 1) were premachined to a rectangular shape. They were then clamped in position in a tungsten inert gas automatic welding machine and welded without filler rod. The radius was machined in the same manner as for the unnotched specimen except that spacers were placed between the fusion-welded specimens away from the weld to compensate for weld bulge while stacked for machining. The weld bulge was left as welded.

Welding procedures.- Prior to welding the spotwelded and fusion-welded components, oxidation was removed from the PH 15-7 Mo, AM 350 DA, and Ti-4Al-3Mo-1V materials by a grit-blast process. Prior to welding fatigue specimens, one sample specimen was welded, sectioned, and etched to check penetration and nugget size. Spotwelded shear test qualifying specimens were made according to military specifications (ref. 8) at the beginning and end of a material run and also after 20 fatigue specimens. A 50-kVA three-phase combination seam and spot welder was used for all spotwelds. It has an electrode face diameter of 0.79 cm (5/16 in.) and a tip radius of 7.62 cm (3 in.). The spotweld parameters in the following table provided minimum weld spacing without short circuiting during welding:

Material	Welds per row	Penetration, percent	Nugget diameter	
			mm	in.
PH 15-7 Mo	7	70	3.3	0.13
AM 350 CRT	7	80	5.1	.20
AM 350 DA	7	80	4.6	.18
AISI 301	7	75	4.1	.16
Ti-6Al-4V	5	80	6.1	.24
Ti-4Al-3Mo-1V	5	80	5.8	.23
Ti-8Al-1Mo-1V	5	80	4.8	.19

The fusion welds were made without a filler rod. A 200-ampere welding machine was used; its electrode was made of tungsten, 2-percent thoria, and had a diameter of 1.0 mm (0.040 in.). The fusion-weld parameters for the various materials are given in the following table:

Material	Shield inert gas flow rate, cm^3/s (cu ft/hr)			Current, amperes
	Top (a)	Bottom	Trailing (b)	
PH 15-7 Mo	240 (30)	[a]160 (20)	0	19
AM 350 CRT	390 (50)	[c]120 (15)	0	24
AM 350 DA	390 (50)	[c]120 (15)	0	24
AISI 301	390 (50)	[c]120 (15)	0	24
Ti-6Al-4V	240 (30)	[b]40 (5)	160 (20)	44
Ti-4Al-3Mo-1V	240 (30)	[b]40 (5)	240 (30)	46
Ti-8Al-1Mo-1V	240 (30)	[b]240 (30)	240 (30)	42

[a]75-percent helium, 25-percent argon.
[b]Argon.
[c]Helium.

Handling and Treatment of Specimens

General requirements.- Sheets were covered with protective paper prior to shearing. Specimens were not scribed, scratched, or marred in any way. Specimens were separated by paper or racked in designated shipping containers. Handling of specimens was at all times conducive to the retention of a scratch-free and chemically clean surface. The special treatment given each material is outlined in the following table:

Material	Cleaning method (*)	Grit-blast oxidation removal
PH 15-7 Mo	A	Yes
AISI 301	B	No
AM 350 CRT	B	No
AM 350 DA	B	Yes
Ti-6Al-4V	C	No
Ti-4Al-3Mo-1V	C	Yes
Ti-8Al-1Mo-1V,An	C	No
Ti-8Al-1Mo-1V,DAn	C	No
RR 58	D	No
2024-T81	D	No

*See next section for description of methods.

Cleaning methods.- The specimens were cleaned both before heat treatment and immediately before insertion into oven at 560 K (550° F). The different cleaning processes used are as follows:

Method A: (1) Remove markings, such as manufacturer's stamp, crayon, etc., by using acetone or alcohol and cloth.

(2) Vapor degrease by using trichlorethylene vapor.

(3) Hand scrub using fiber brush and a detergent.

(4) Hand scrub and rinse in hot running water.

(5) Rinse in cold running water.

(6) Check for uniform wetting of specimen surface.

(7) Wipe dry with clean cloth or paper towels.

Method B: (1) Remove markings, such as manufacturer's stamps, crayon, etc., by using acetone or alcohol and cloth.

(2) Vapor degrease by using trichlorethylene vapor.

(3) Rinse in hot water.

(4) Immerse in nitric acid, 20 percent by volume, for approximately 5 minutes.

(5) Wash in hot water.

(6) Rinse in cold water.

(7) Check for uniform wetting of specimen surface.

(8) Wipe dry with clean cloth or paper towels.

Method C: (1) Immerse in alkaline cleaner for 10 minutes. Use at 355 K (180° F) to 366 K (200° F).

(2) Rinse in hot water 2 to 3 minues.

(3) Immerse in nitric acid, 20 percent by volume, for 30 seconds.

(4) Rinse in hot water, agitated.

(5) Rinse in cold water, that is, agitated and continuously supplied.

(6) Check for uniform wetting of specimen surface.

(7) Wipe dry with clean cloth or paper towels.

Method D: (1) Remove manufacturer's stamp and other markings with acetone and cloth.

(2) Vapor degrease by using trichloroethylene vapor.

(3) Rinse in hot water.

(4) Rinse in clean cold water.

(5) Dry with clean cloth or paper towels.

Chemical Compositions

The chemical compositions determined by the manufacturers of the materials used in this investigation and the respective densities are listed in the following table:

Element	Weight percentage of element in –									
	PH 15-7 Mo	AM 350	AISI 301	Ti-6Al-4V (a)	Ti-4Al-3Mo-1V (a)	Ti-8Al-1Mo-1V (a)	RR 58		2024	
							Core	Cladding	Core	Cladding
Al	1.14			6.1	4.4	7.9	Balance	Balance	Balance	Balance
C	0.063	0.080	0.089	0.026	0.015	0.030				
Co			0.05							
Cr	14.96	16.80	17.30						0.1	0.1
Cu							1.8 to 2.7		3.8 to 4.9	0.1
Fe	Balance	Balance	Balance	0.15	0.16	0.10	0.9 to 1.4		0.05	[b]0.7
H_2				0.011	0.010	0.005				
Mg							1.2 to 1.8		1.2 to 1.8	
Mn	0.55	0.76	0.15				0.2		0.3 to 0.9	0.05
Mo	2.15	2.80	0.16		3.0	1.1				
N_2				0.013	0.011	0.012				
Ni	7.23	4.15	7.70				0.8 to 1.4			
P	0.020	0.019	0.023							
Pb							0.05			
S	0.011	0.012	0.017							
Si	0.44	0.30	0.47				0.15 to 0.25		0.05	(c)
Sn							0.25			
Ti				Balance	Balance	Balance	0.2			
V				4.0	1.1	1.1				
Zn							0.1	0.8 to 1.2	0.25	(c)
Density of alloy, Mg/m^3 (lbm/in^3)	7.67 (0.277)	7.92 (0.286)	7.95 (0.287)	4.46 (0.161)	4.51 (0.163)	4.32 (0.156)	274 (0.099)		2.77 (0.100)	

[a]Average for different heats.
[b]Includes Si and Zn.
[c]Included in percentage of Fe.

Heat Treatments

The heat treatments for the materials are given in the following table:

Material	Treatment
PH 15-7Mo (TH 1050)	Annealed at 1340 K (1950° F) and air cooled by producer;* austenitized at 1030 K ± 14 K (1400° F ± 25 F°) for 90 minutes in argon; quenched to 290 K + 0, -5 K (60° F + 0 F°, -10 F°) within 1 hour, held for 30 minutes; aged at 840 K ± 5 K (1050 °F ± 10 F°) for 90 minutes in argon; air cooled to room temperature.
AM 350 CRT	Cold rolled 20 percent; tempered 3 to 15 minutes at 770 K (930° F); air cooled by producer.
AM 350 DA	Annealed between 1280 K and 1350 K (1850° F and 1975° F), air cooled by producer.* Aged at 1020 K ± 14 K (1375° F ± 25 F°) for 3 hours in argon; air cooled to 300 K + 0, -5 K (80° F + 0 F°, -10 F°); aged at 730 K ± 14 K (850° F ± 25 F°) for 3 hours in argon; air cooled to room temperature.
AISI 301 CR	Annealed at 1370 K (2000° F), air cooled; cold reduced 56 percent by producer.
Ti-6Al-4V An**	Annealed 1 hour at 1075 K (1475° F), furnace cooled at 980 K (1300° F), air cooled by producer.
Ti-4Al-3Mo-1V STA	Solution treated for 20 minutes at 1170 K (1650° F) and water quenched by producer; aged 4 hours at 840 K (1050° F) in argon, air cooled to room temperature.
Ti-8Al-1Mo-1V An	Annealed 8 hours at 1060 K (1450° F) and furnace cooled by producer.
Ti-8Al-1Mo-1V DAn	Annealed 8 hours at 1060 K (1450° F), furnace cooled; annealed 15 minutes at 1060 K (1450° F) air cooled by producer.
Clad RR 58 STA	Solution treated at 800 to 810 K (977° to 995° F), water quenched; aged 20 hours at 470 K (392° F) by producer.
Clad 2024 STA(T81)	Solution treated at 760 to 770 K (910° to 930° F), water quenched; cold worked; precipitation heat treated at 460 K (375° F) 11 to 13 hours by producer.

*Specimens that were fusion welded before heat treatment were welded at this stage of heat treatment.

**Fusion-welded specimens were stress relieved by heating to 890 K (1150° F) in argon for 1 hour and air cooling within 72 hours after welding.

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TABLE I.- AVERAGE TENSILE PROPERTIES AT ROOM TEMPERATURE AFTER ELEVATED-TEMPERATURE EXPOSURE[1]

[Tensile specimens loaded parallel to rolling direction]

Material	Exposure temperature, K	Exposure temperature, °F	Exposure time, hr	S_u, MN/m²	S_u, ksi	S_y (2), MN/m²	S_y (2), ksi	e, percent (3)	Number of specimens tested
PH 15-7Mo (TH 1050)	560	550	0	1380	201	1350	196	7	4
			2 200	1410	205	1380	200	7	4
			4 400	1430	208	1390	202	7	4
			8 800	1450	210	1410	205	7	4
			17 500	1490	216	1430	208	6	4
			26 300	1490	216	1440	209	7	6
AM 350, 20 percent CRT	560	550	0	1380	201	1280	185	19	12
			2 200	1320	192	1290	187	20	4
			4 400	1340	194	1300	189	20	4
			8 800	1300	188	1280	186	18	4
			17 500	1320	191	1300	188	21	4
			26 300	1320	192	1300	188	20	8
AM 350, double-aged	560	550	0	1310	190	1090	158	13	23
			2 200	1320	192	1090	158	13	5
			4 400	1320	191	1080	157	13	5
			8 800	1300	188	1080	156	12	4
			17 500	1300	189	1100	159	13	5
			26 300	1310	190	1080	157	12	10
AISI 301, 50 percent CR	560	550	0	1490	216	1400	203	4	7
			2 200	1590	231	1370	199	3	4
			4 400	1590	230	1390	201	3	4
			8 800	1590	230	1390	202	2	4
			17 500	1590	231	1410	205	2	4
			26 300	1610	233	1390	202	3	8
Ti-6Al-4V, annealed	560	550	0	1030	149	979	142	12	8
			2 200	1090	158	1030	149	11	3
			4 400	1100	159	1020	148	10	4
			8 800	1100	159	1060	153	10	4
			17 500	1120	162	1060	154	11	4
			26 300	1100	159	1060	153	11	8
Ti-4Al-3Mo-1V, aged	560	550	0	979	142	840	122	10	8
			2 200	979	142	840	122	10	4
			4 400	979	142	840	122	9	4
			8 800	979	142	834	121	10	4
			17 500	986	143	855	124	9	4
			26 300	1000	145	855	124	9	8

[1]Numbers above dashed lines are from reference 1.

[2]0.2-percent offset.

[3]5.1-cm (2-in.) gage length.

TABLE I.- AVERAGE TENSILE PROPERTIES AT ROOM TEMPERATURE AFTER ELEVATED-TEMPERATURE EXPOSURE[1] – Concluded

Material	Exposure temperature, K	Exposure temperature, °F	Exposure time, hr	S_u, MN/m^2	S_u, ksi	S_y (2), MN/m^2	S_y (2), ksi	e, percent (3)	Number of specimens tested
Ti-8Al-1Mo-1V, single annealed	560	550	0	1080	157	1000	145	16	10
			2 200	1080	157	992	144	16	4
			4 400	1080	156	1010	146	17	5
			8 800	1080	157	1010	146	15	3
			17 500	1060	154	1000	145	15	4
			26 300	1070	155	1000	145	15	6
Ti-8Al-1Mo-1V, duplex annealed	560	550	0	1030	150	945	137	13	2
			2 200	1040	151	945	137	12	4
			4 400	1060	154	952	138	13	4
			8 800	1060	154	959	139	12	4
			17 500	1060	154	952	138	12	4
			32 100	1050	152	952	138	14	11
RR 58, clad	340	250	0	410	59.5	370	53.8	7	8
			2 200	406	59.0	372	54.0	7	4
			4 400	408	59.2	374	54.2	7	4
			8 800	411	59.6	374	54.2	8	4
			17 500	409	59.3	374	54.3	7	4
			26 300	406	59.0	356	51.7	7	4
	420	300	0	410	59.5	370	53.8	7	8
			2 200	402	58.3	362	52.5	8	4
			4 400	396	57.5	350	50.9	8	4
			8 800	391	56.7	343	49.8	8	4
2024-T81, clad	340	250	0	445	64.6	396	57.5	7	9
			2 200	447	64.9	398	57.8	7	3
			4 400	448	65.0	404	58.5	7	3
			8 800	451	65.5	402	58.4	7	3
			17 500	443	64.2	395	57.3	8	3
			26 300	430	62.3	361	52.4	8	3
	420	300	0	445	64.6	396	57.5	7	9
			2 200	427	62.0	367	53.2	8	3
			4 400	429	62.1	367	53.2	7	2
			8 800	418	60.6	353	51.1	7	3
			17 500	402	59.9	346	50.2	8	3

[1]Numbers above dashed lines are from reference 1.
[2]0.2-percent offset.
[3]5.1-cm (2-in.) gage length.

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE

(a) PH 15-7 Mo steel; condition TH 1050; S_{mean} = 280 MN/m^2 (40 ksi)

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 1		
1100	160	32
		41
		44
970	140	75
		84
		99
		119
830	120	73
		119
		178
780	113	158
		710
		2 873
745	108	973
		3 516
K_T = 4		
459	66.5	27
450	65	54
430	62	41
		45
		78
		94
400	58	124
		>10 000
390	57	>10 000
Spotwelded		
520	75	19
		20
		21
		27
380	55	242
		250
		252
350	50	810
		2 586

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Fusion welded after heat treatment		
725	105	20
		22
		33
704	102	21
		72
690	100	36
		42
		49
660	95	44
		50
		60
620	90	24
		68
		115
621	90	120
		129
		130
		170
		171
		184
		328
		355
600	87	127
		215
		369
587	85	329
		1 065
566	82	591
545	79	2 233
		8 140
538	78	>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Fusion welded before heat treatment		
794	115	26
		32
		70
759	110	20
		57
		89
		93
725	105	47
		52
		61
		261
690	100	80
		85
		97
		129
		220
656	95	275
		337
		728
635	92	206
		257
		314
621	90	58
		108
		198
		223
		574
		>10 000
600	87	843
		1 352
		>10 000
587	85	6 828
		>10 000
		>10 000

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(b) AM 350 20-percent CRT steel; S_{mean} = 280 MN/m^2 (40 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
1104	160	20
		26
		26
1070	155	40
		43
		43
1035	150	46
		60
		68
966	140	57
		80
		96
897	130	147
		170
		188
863	125	92
		220
		572
		691
		1 372
828	120	427
		587
		1 197
794	115	272
		453
		684
773	112	211
		708
		1 019
759	110	1 048
		>10 000
		>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
587	85	11
		11
		11
552	80	16
		16
		22
497	72	23
		23
		28
449	65	38
		41
		49
		53
		62
414	60	67
		67
		94
400	58	71
		87
		>10 000
393	57	84
		1 245
		1 792
380	55	110
		174
		1 026
		1 862
359	52	4 002
		>10 000
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
518	75	24
		26
		30
		39
483	70	43
		56
449	65	87
		88
		88
		91
		98
414	60	191
		240
		249
		250
380	55	429
		510
		610
		643
		844
366	53	830
		1 296
352	51	>300
		1 402
		1 590
338	49	>10 000
331	48	9 152

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
794	115	16
		17
		20
759	110	21
		32
		33
725	105	52
		59
		59
690	100	131
		141
		163
		180
		204
656	95	239
		261
		677
635	92	141
		1 764
		2 895
621	90	379
		959
		1 315
		3 220
600	87	243
		>10 000
		>10 000
		>10 000
587	85	>10 000
		>10 000
		>10 000
572	83	>10 000

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(c) AM 350 doubled-aged steel; S_{mean} = 280 MN/m^2 (40 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
1104	160	13
		15
		17
1035	150	26
		27
		37
966	140	37
		37
		43
		45
		74
		96
		96
932	135	116
		259
897	130	95
		170
		177
		354
863	125	565
		612
		1 398
		2 925
		>10 000
828	120	164
		165
		>10 000
		>10 000
794	115	3 571
		>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
552	80	9
		10
		14
524	76	14
		18
		20
497	72	20
		25
		38
469	68	22
		25
		49
449	65	47
		54
		87
428	62	71
		85
		9 141
414	60	66
		>10 000
		>10 000
		>10 000
359	52	>10 000
345	50	>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
518	75	18
		24
		21
483	70	34
		38
		43
		47
449	65	71
		83
		86
414	60	111
		159
		176
		231
393	57	255
		273
		289
		326
380	55	289
		330
		960
		>10 000
366	53	5 336
359	52	3 489
		4 554
		8 089
352	51	1 942
		2 112
345	50	>10 000

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(c) AM 350 double-aged steel; S_{mean} = 280 MN/m^2 (40 ksi) – Concluded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Fusion welded after heat treatment		
863	125	5
		8
828	120	8
		9
		11
794	115	12
		13
		25
759	110	20
		33
		47
725	105	69
		70
		71
		137
690	100	75
		154
		159
		180
		188
		275
669	97	75
		246
		251
		278
656	95	136
		457
		524
		550
		738
635	92	306
		383
		700
621	90	705
		994
		1 293
		1 590
		>10 000
Fusion welded after heat treatment – Concluded		
600	87	1 571
		>10 000
587	85	1 501
		>10 000
		>10 000
		>10 000
552	80	>10 000
		>10 000
Fusion welded before heat treatment		
966	140	11
		25
		26
		29
897	130	27
		30
		32
		34
		35
863	125	44
		117
828	120	45
		49
		62
		89
794	115	107
		154
		202
759	110	135
		141
		238
725	105	334
		366
690	100	151
		366
		487
669	97	787
		2 823
662	96	624
		>10 000
635	92	>10 000

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(d) AISI 301, 50-percent CR steel; S_{mean} = 280 MN/m^2 (40 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
966	140	18
		21
		23
		36
		37
		51
897	130	32
		33
		37
842	122	1 741
828	120	47
		51
		63
		68
		73
		81
		87
		167
		425
		841
		>10 000
759	110	72
		228
		1 964
		>8 046
		>10 000
		>10 000
725	105	3 693
690	100	75
		106
		176
		210
		1 720
		6 770
		>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
483	70	17
		18
		21
449	65	20
		28
		30
414	60	43
		52
		59
		>10 000
393	57	62
		103
		7 529
		>10 000
		>10 000
		>10 000
380	55	94
		108
		271
		425
		9 879
359	52	506
		630
		5 265
		>10 000
345	50	2 018
		7 904
		>10 000
331	48	>10 000
		>10 000
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
483	70	18
		19
		19
449	65	30
		32
		36
		54
414	60	71
		71
		76
		125
393	57	110
		126
		145
380	55	137
		167
		186
		332
366	53	256
		257
		294
359	52	290
		387
		437
		>10 000
352	51	387
		422
		608
345	50	695
		777
331	48	>10 000
		>10 000

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
600	87	61
		66
		115
587	85	39
		48
		103
573	83	309
		312
		573
566	82	86
		108
		9 991
		>10 000
532	80	114
		198
		>10 000
		>10 000
538	78	>10 000
		>10 000
518	75	>10 000
		>10 000
		>10 000

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(e) Ti-6Al-4V annealed titanium; S_{mean} = 170 MN/m^2 (25 ksi)

K_T = 1

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
828	120	16
		22
		28
759	110	14
		52
		54
690	100	46
		94
		145
662	96	117
656	95	78
		113
		321
		691
621	90	615
		902
587	85	62
		544
		600
		847
		1 058
552	80	342
		901
		1 925
		2 116
		2 512
524	76	2 091
		2 176
		3 087
497	72	2 910
		6 526
		9 081
483	70	2 648
		2 695
469	68	4 345
		5 360
		7 049

K_T = 4

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
414	60	7
380	55	12
		12
		16
345	50	17
		21
		26
311	45	13
		24
		31
276	40	57
		57
		112
		152
		315
262	38	54
		59
255	37	83
		3 409
248	36	60
		85
		1 870
242	35	76
		>10 000
235	34	1 846
		2 105
		2 704
		>10 000
228	33	206
		8 448
		>8 075
221	32	>10 000
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
331	48	21
		28
		28
311	45	32
		35
		51
		58
290	42	55
276	40	49
		72
		86
		132
		133
262	38	222
255	37	99
		124
		175
		178
242	35	334
		415
		592
235	34	>10 000
		>10 000
228	33	>10 000
		>10 000
207	30	>10 000
		>10 000
		>10 000

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
621	90	19
		24
		32
587	85	18
		22
		23
552	80	26
		36
		66
518	75	55
		80
		98
483	70	41
		58
		107
		277
		537
469	68	503
		1 453
		3 293
449	65	112
		1 026
		7 327
		>10 000
435	63	404
		1 061

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(f) Ti-4Al-3Mo-1V aged titanium; S_{mean} = 170 MN/m^2 (25 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
759	110	11
		14
		15
690	100	14
		16
		21
621	90	17
		19
		29
580	84	28
		41
566	82	34
		56
		78
552	80	49
518	75	41
		65
		67
483	70	69
		80
		178
		200
469	68	126
		193
		316
		>10 000
455	66	201
		213
		>10 000
449	65	>10 000
435	63	>10 000
414	60	>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
311	45	10
290	42	13
		13
		16
276	40	18
		19
		23
255	37	28
		31
		32
242	35	44
		51
		63
228	33	79
		82
		145
221	32	182
		199
		201
		>10 000
		>10 000
214	31	476
		>10 000
		>10 000
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
331	48	27
		31
		36
311	45	34
		40
		49
		51
290	42	70
		82
		97
276	40	84
		108
		155
		167
		222
262	38	181
		>10 000
		>10 000
		>10 000
		>10 000
		>10 000
242	35	>10 000
		>10 000

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
518	75	16
		17
		19
483	70	26
		30
		39
449	65	27
		29
		56
428	62	32
		36
		91
		169
414	60	47
		78
		80
		>10 000
400	58	48
		73
380	55	61
		66
		>10 000
366	53	2 032
		>10 000
		>10 000
345	50	>10 000
		>10 000

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(g) Ti-8Al-1Mo-1V annealed titanium; $S_{mean} = 170\ MN/m^2$ (25 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
759	110	21
		22
		28
690	100	19
		23
		57
656	95	24
		27
		45
		64
621	90	38
		59
		80
		89
		127
587	85	46
		71
		97
		979
		1 365
		9 420
552	80	122
		124
		138
		505
		1 471
		1 522
531	77	2 960
		4 435
518	75	262
		319
		2 804
497	72	3 275
		>10 000
		1 840
483	70	7 921
		9 955
		1 595
		>10 000
		>10 000
455	66	>10 000
		>10 000
		>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
345	50	15
		19
		26
324	47	15
		20
		21
311	45	24
		58
		221
297	43	24
		71
		444
290	42	75
		562
276	40	429
		453
		459
		635
		642
255	37	110
		569
		695
242	35	1 167
		1 691
228	33	733
		1 651
		1 796
221	32	3 571
		9 252
		>10 000
207	30	>10 000
		>10 000
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
331	48	24
		25
		32
		81
311	45	32
		58
		80
		109
297	43	46
		47
		57
		97
		139
276	40	73
		105
		226
262	38	107
		155
		196
248	36	351
		439
242	35	185
		289
		432
		659
235	34	7 987
		8 864
		>10 000
228	33	593
		>10 000

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
621	90	25
		26
		27
587	85	24
		32
		33
552	80	28
		29
		38
538	78	55
		80
524	76	31
		104
		1 374
518	75	49
		74
		96
		173
511	74	262
497	72	54
		62
		75
		620
483	70	664
		893
		2 212
469	68	91
		1 693
		2 801
449	65	1 932
442	64	548
		1 905
		5 760
428	62	2 896
		5 066
		5 985
		6 588
414	60	4 227
		5 365
		>10 000
400	58	4 943
		5 615
		8 599

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Continued

(h) Ti-8Al-1Mo-1V duplex annealed; $S_{mean} = 170\ MN/m^2$ (25 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
965	140	1.19
		2.03
931	135	2.78
		3.09
		4.00
		6.36
		8.83
		10
827	120	16
		17
		18
758	110	31
		32
		39
		47
		48
690	100	68
		71
		80
655	95	106
		118
		124
		162
620	90	93
		137
		145
		308
		3 120
606	88	4 544
600	87	151
		793
		1 360
		4 640
586	85	3 951
		9 210
		>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
517	75	1.12
483	70	2.08
448	65	3.35
		3.69
		3.93
414	60	6.38
		6.67
		6.73
379	55	9.73
		12
		12
345	50	20
		21
		26
310	45	38
276	40	75
		85
		91
255	37	190
		311
241	35	6 491
		>10 000
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
551	80	3.3
		3.8
482	70	6.7
		8.1
414	60	10
		12
		16
331	48	24
		30
		32
310	45	34
		40
		47
276	40	90
		93
		100
		158
		169
		185
		224
		225
241	35	290
		347
		692
228	33	4 727
		>10 000
		>10 000

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
965	140	1.8
896	130	2.6
		3.9
827	120	5.1
		5.8
759	110	9.2
		10
690	100	14
		16
586	85	38
		40
517	75	39
		43
		64
482	70	71
		2 339
		8 678
		>10 000
449	65	196
		1 033
		8 547
		8 786

TABLE II.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE BEFORE EXPOSURE – Concluded

(i) RR 58 clad; S_{mean} = 90 MN/m^2 (13 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
345	50	6.02
		10
310	45	19
		19
		26
		28
276	40	34
		42
		50
		63
241	35	86
		99
		111
		121
207	30	152
		155
		159
		160
		187
172	25	415
		520
		591
		1 215
159	23	1 000
152	22	1 115
		1 423
		>10 000
		>10 000
138	20	>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
207	30	1.68
		1.73
		1.75
		1.84
172	25	7
		9
		9
		10
138	20	42
		43
		50
		53
124	18	122
		159
		194
		198
117	17	177
		1 438
		5 545
110	16	>10 000
		>10 000

(j) 2024-T81; S_{mean} = 90 MN/m^2 (13 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
400	58	1.10
		2.39
		3.03
379	55	4.88
		6.31
		8.34
		8.66
345	50	12
		13
		14
		14
310	45	15
		22
		23
		24
		25
		26
		30
		31
276	40	30
		32
		36
		36
		38
		46
		49
		60
241	35	54
		73
		80
		88
		102
207	30	193
		206
		243
		376
172	25	487
		1 303
		1 363
		2 816
165	24	1 128
		8 097
159	23	>10 000
152	22	>10 000
		>10 000
138	20	>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
207	30	2.24
		2.59
		2.70
		3.10
179	26	7
		8
		8
		8
		8
		9
		9
		9
159	23	20
		20
		22
		28
138	20	47
		58
		60
		71
124	18	111
		153
		219
		285
		341
		396
		426
		752
110	16	>10 000
		>10 000
		>10 000

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560 K (550° F) FOR 26 300 HOURS

(a) PH 15-7Mo, TH 1050; S_{mean} = 280 MN/m^2 (40 ksi)

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 1		
1100	160	17
		21
		27
1040	150	21
		30
		36
970	140	9
		30
		60
900	130	61
		165
		219
830	120	89
		121
		130
780	113	192
		306
745	108	322
		>2 138
725	105	675
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 4		
520	75	9
		10
		11
480	70	15
		15
		27
450	65	26
		30
		32
430	62	31
		42
		48
410	60	69
		94
400	58	102
		2 229
		3 696
390	56	>10 000
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Spotwelded		
520	75	32
		32
		37
480	70	46
		54
		54
460	67	69
		93
		93
410	60	171
		208
		210
380	55	441
		460
		542
360	52	1 065
		4 240
350	50	>10 000
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Fusion welded after heat treatment		
760	110	18
		32
		48
620	90	285
590	85	121
		686
570	82	127
550	79	385
		>10 000
Fusion welded before heat treatment		
860	125	23
		25
		30
790	115	32
		92
		121
760	110	35
730	105	58
		64
		83
690	100	110
		121
		233

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560 K (550° F) FOR 26 300 HOURS – Continued

(b) AM 350, 20-percent CRT; S_{mean} = 280 MN/m^2 (40 ksi)

$K_T = 1$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
1040	150	38
		41
		42
970	140	35
		45
		62
860	125	53
		118
		270
830	120	93
		140
		256
760	110	84
		592
		4 178
730	105	7 144
		>10 000
		>10 000

$K_T = 4$

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
590	85	8
		10
		11
520	75	14
		17
		20
450	65	29
		29
		35
380	55	85
		87
		94
		2 184
360	52	146
		5 041
		>10 000

Spotwelded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
550	80	16
		17
		20
520	75	26
		32
		33
480	70	48
		62
		62
450	65	99
		103
		120
410	60	232
		271
		284
380	55	434
		674
		837
		897
		904
360	52	2 319
		3 315
		>10 000
350	50	>10 000
		>10 000

Fusion welded

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
790	115	7
		8
		10
730	105	35
		49
		55
690	100	39
		72
		119
660	95	35
		39
		354
620	90	585
		658
		919
610	88	976
		>10 000
600	87	574
		>10 000

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560 K (550° F) FOR 26 300 HOURS – Continued

(c) AM 350, double-aged; S_{mean} = 280 MN/m² (40 ksi)

S_{max}		N, kilocycles
MN/m²	ksi	
K_T = 1		
1100	160	11
		12
		13
1040	150	9
		17
		18
970	140	30
		34
		44
900	130	74
		84
		375
860	125	70
		360
		459
840	122	157
		195
		645
830	120	266
820	119	265
		440
810	118	>10 000
K_T = 4		
550	80	4.1
		6
		6.5
480	70	13
		19
		25
450	65	23
		27
		57

S_{max}		N, kilocycles
MN/m²	ksi	
K_T = 4 – Concluded		
410	60	39
		40
		80
390	57	58
		>10 000
		>10 000
380	55	338
		>10 000
		>10 000
359	52	>10 000
Spotwelded		
520	75	27
		30
		30
480	70	33
		43
		52
450	65	76
		86
		88
410	60	163
		187
		215
380	55	255
		494
		754
360	52	870
		4 542
350	51	>10 000
350	50	>10 000

S_{max}		N, kilocycles
MN/m²	ksi	
Fusion welded after heat treatment		
860	125	0.8
810	117	3.6
		4.9
		6.7
760	110	17
		18
		21
690	100	56
		66
		73
620	90	271
		461
		895
590	86	565
590	85	1 977
570	83	>10 000
550	80	>10 000

S_{max}		N, kilocycles
MN/m²	ksi	
Fusion welded before heat treatment		
900	130	21
		28
		38
840	122	45
		63
		75
790	115	89
		116
		159
720	105	239
		437
		742
690	100	547
		566
		692
670	97	274
		704
		>10 000
660	95	728
		>10 000
		>10 000

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560 K (550° F) FOR 26 300 HOURS – Continued

(d) AISI 301, 50-percent cold rolled; S_{mean} = 280 MN/m^2 (40 ksi)

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 1		
930	135	35
		37
		213
860	125	43
		60
		231
		>10 000
		>10 000
		>10 000
790	115	83
		88
		8 486
760	110	196
		>10 000
		>10 000
660	95	16
		23
520	75	397

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 4		
520	75	11.1
		11.4
		13.0
450	65	20
		21
		33
410	60	36
		40
		6 313
380	55	53
		1 187
		4 464
350	50	>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Spotwelded		
480	70	17
		18
		23
450	65	34
		34
		38
410	60	69
		73
		79
380	55	137
		165
		179
360	52	295
		311
		314
330	48	1 110
		1 560
320	47	>10 000
310	45	>10 000
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Fusion welded		
660	95	19
600	87	44
		44
		81
570	82	74
		76
		108
530	77	147
		206
		>10 000
520	75	>10 000
		>10 000

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560 K (550° F) FOR 26 300 HOURS – Continued

(e) Ti-6Al-4V, annealed; S_{mean} = 170 MN/m^2 (25 ksi)

S_{max}		N, kilocycles	S_{max}		N, kilocycles	S_{max}		N, kilocycles	S_{max}		N, kilocycles
MN/m^2	ksi		MN/m^2	ksi		MN/m^2	ksi		MN/m^2	ksi	
K_T = 1			K_T = 4			Spotwelded			Fusion welded		
900	130	8	410	60	4.4	410	60	11.5	620	90	16.5
		10			4.5			12.2			21
		11			4.5			13.0			25.3
830	120	19	360	52	8.5	350	50	25	550	80	20
		29			9.2			35			26
		34			9.4			42			38
760	110	27	310	45	15	310	45	55	520	75	43
		50			19			65			84
		96			21			91			117
690	100	64	280	40	28	280	40	108	480	70	44
		65			29			126			51
		81			30			175			58
		581	240	35	69	260	38	>10 000			1 406
		833			82	250	37	>10 000			>10 000
620	90	432			89				450	65	144
		1 080	230	34	112	240	35	>10 000			
		1 403			>10 000						
590	85	2 919	230	33	>10 000						
		3 057			>10 000						
		8 981	220	32	>10 000						
		>10 000									
520	75	>10 000									
		>10 000									
		>10 000									

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560° K (550° F) FOR 26 300 HOURS – Continued

(f) Ti-4Al-3Mo-1V, aged; S_{mean} = 170 MN/m² (25 ksi)

$K_T = 1$

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
760	110	10
		12
		16
690	100	19
		20
		21
620	90	25
		27
		29
550	80	34
		58
		70
480	70	44
		67
		69
		>10 000
		>10 000
		>10 000
		>10 000
		>10 000
470	70	146
		>10 000
		>10 000
450	65	107
		122
		126

$K_T = 4$

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
310	45	10.6
		11.0
		12.0
290	42	14
		16
		20
280	40	18
		21
		22
250	36	296
240	35	46
		60
		69
230	33	77
		84
		91
		98
		>10 000
220	32	132
		289
		>10 000

Spotwelded

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
350	50	17
		18
		22
310	45	34
		35
		39
280	40	68
		70
		79
260	38	113
		113
		170
260	37	219
250	36	308
240	35	242
		467
		>10 000
230	33	>10 000
220	32	>10 000

Fusion welded

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
520	75	18
		26
480	70	24
		28
		46
430	62	46
		68
		200
410	60	50
		50
		4863
400	58	36

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560° K (550° F) FOR 26 300 HOURS – Continued

(g) Ti-8Al-1Mo-1V, annealed; S_{mean} = 170 MN/m^2 (25 ksi)

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 1		
760	110	20
		21
		30
690	100	42
		47
		53
620	90	64
		86
		135
550	80	648
		967
		3 198
		>10 000
520	75	385
480	70	795
		>10 000
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
K_T = 4		
350	50	9
		10
		12
310	45	15
		22
		25
280	40	39
		45
		45
		74
		475
240	35	342
		659
		1 368
220	32	1 810
		3 211
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Spotwelded		
370	53	11.7
		15.5
		21.9
330	48	68
		77
		94
310	45	43
		48
		74
		140
280	40	139
		167
		204
260	38	153
		153
		167
		291
		394
240	35	332
		1 013
		>10 000
230	33	>10 000
		>10 000
		>10 000

S_{max}, MN/m^2	S_{max}, ksi	N, kilocycles
Fusion welded		
620	90	23
		28
		37
550	80	32
		72
		154
480	70	71
		78
		123
		507
		556
		1 128
		1 668
		1 734
		2 488
450	65	104
		3 078
		5 173
		6 242
		6 890
		>10 000
410	60	8 236
		9 836
		>10 000

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560° K (550° F) FOR 26 300 HOURS – Continued

(h) Ti8Al-1Mo-1V, duplex annealed;[1] S_{mean} = 170 MN/m² (25 ksi)

S_{max}		N, kilocycles	S_{max}		N, kilocycles	S_{max}		N, kilocycles	S_{max}		N, kilocycles
MN/m²	ksi		MN/m²	ksi		MN/m²	ksi		MN/m²	ksi	
K_T = 1			K_T = 4			Spotwelded			Fusion welded		
900	130	12	380	55	6	450	65	10	760	110	10
		14			6			12			11
		20			9			14			15
760	110	34	310	45	17	340	50	25	620	90	24
		44			18			36			24
		45			20	280	40	92			25
		47	260	37	68			113	520	75	52
690	100	116			74			115			202
		126			75			138			937
		137	240	35	150	230	34	458	480	70	67
650	94	728	240	34	170			949			89
		>10 000	220	32	>10 000	220	32	>10 000			2 017
		>10 000	210	30	>10 000	210	30	>10 000			2 701
620	90	9 860									>10 000
		>10 000							450	65	713
		>10 000									
580	85	>10 000									

[1]Exposed 32 100 hours at 560 K (550° F).

TABLE III.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER EXPOSURE TO 560° K (550° F) FOR 26 300 HOURS – Concluded

(i) RR 58, clad;[1] S_{mean} = 90 MN/m² (13 ksi)

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
	K_T = 1	
340	50	3.73
		8.61
		8.73
		8.77
310	45	21
		23
		26
		30
280	40	27
		39
		41
		42
240	35	65
		71
		73
		75
210	30	172
		180
		184
		192
170	25	399
		520
		534
		605
160	23	595
		868
		1 070
		1 285
150	22	1 610
		2 205
		2 689
		4 318
140	21	>10 000
		>10 000

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
	K_T = 4	
210	30	1.52
		1.96
		2.00
		2.00
170	25	7.79
		9.94
		11
		12
140	20	49
		60
		76
		75
120	18	109
		146
		210
		218
110	16	1 399
		1 403
		3 363
100	15	>10 000
		>10 000

[1]Exposed for 26 300 hours at 390 K (250° F).

(j) 2024-T81, clad;[1] S_{mean} = 90 MN/m² (13 ksi)

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
	K_T = 1	
240	35	44
		50
		50
		51
		52
		56
		60
		61
		71
		78

S_{max}, MN/m²	S_{max}, ksi	N, kilocycles
	K_T = 4	
140	20	32
		40
		40
		42
		45
		45
		46
		46
		49
		51

[1]Exposed for 26 300 hours at 390 K (250° F).

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER INTERMEDIATE EXPOSURES

[Data to the left of the dashed line are from ref. 1]

(a) PH 15-7 Mo, TH 1050, exposed at 560 K (550° F); S_{mean} = 280 MN/m^2 (40 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 779 MN/m^2 (113 ksi)			
240	106	261	144
338	159	825	165
348	208	908	362
459	258	1203	4062
787	310	1322	
K_T = 4; S_{max} = 430 MN/m^2 (62 ksi)			
47	36	43	34
49	45	46	42
66	47	54	48
67	58	54	50
69	155	74	60
Spotwelded; S_{max} = 460 MN/m^2 (67 ksi)			
46	59	74	83
48	59	79	92
51	68	101	98
64	69	107	103
72	98	111	109
Fusion welded after heat treatment; S_{max} = 620 MN/m^2 (90 ksi)			
173	176	62	120
174	197	161	175
196	258	296	177
239	293	270	178
260	615	389	480
Fusion welded before heat treatment; S_{max} = 690 MN/m^2 (100 ksi)			
74	54	53	30
86	58	161	61
90	63	161	84
100	133	165	153
180	263	253	187

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER INTERMEDIATE EXPOSURES – Continued

(b) AM 350, 20-percent CRT, exposed at 560 K (550° F); S_{mean} = 280 MN/m^2 (40 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
$K_T = 1$; S_{max} = 900 MN/m^2 (130 ksi)			
42	93	53	49
71	126	117	92
149	261	139	130
229	278	200	174
286	364		344
$K_T = 4$; S_{max} = 450 MN/m^2 (65 ksi)			
38	36	32	37
41	43	37	37
44	45	38	43
48	50	39	43
7690	6629	43	44
Spotwelded; S_{max} = 380 MN/m^2 (55 ksi)			
579	687	620	904
652	803	690	1098
695	884	817	2594
1233	1312	1161	3410
1795	1547	1666	
Fusion welded; S_{max} = 690 MN/m^2 (100 ksi)			
72	65	55	84
90	69	103	89
111	85	165	103
118	87	205	135
155	90	223	154

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER INTERMEDIATE EXPOSURES – Continued

(c) AM 350, double aged, exposed at 560 K (550° F); S_{mean} = 280 MN/m^2 (40 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 970 MN/m^2 (140 ksi)			
54	52	28	25
61	55	46	34
78	56	61	35
98	57	67	35
107	80	89	52
K_T = 4; S_{max} = 450 MN/m^2 (65 ksi)			
22	35	22	19
33	36	25	29
39	38	26	31
63	50	30	34
132	88	33	41
Spotwelded; S_{max} = 390 MN/m^2 (57 ksi)			
227	217	249	240
263	262	298	289
306	277	329	334
322	329	339	351
	392	375	375
Fusion welded after heat treatment; S_{max} = 690 MN/m^2 (100 ksi)			
40	30	71	51
49	36	103	51
64	43	127	70
81	47	135	75
117	55	244	101
Fusion welded before heat treatment; S_{max} = 790 MN/m^2 (115 ksi)			
81	61	70	59
96	72	78	70
116	85	78	82
196	125	91	126
228	129	249	132

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE

AFTER INTERMEDIATE EXPOSURES – Continued

(d) AISI 301, 50-percent CR, exposed at 560 K (550° F); S_{mean} = 280 MN/m^2 (40 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
$K_T = 1$; S_{max} = 830 MN/m^2 (120 ksi)			
114	113	50	69
282	114	55	93
8 853	201	71	220
>10 000	>10 000	113	464
>10 000		>10 000	>10 000
$K_T = 4$; S_{max} = 410 MN/m^2 (60 ksi)			
37	34	38	36
38	52	46	40
48	62	53	52
66	>10 000	2 036	59
>10 000	>10 000	6 828	68
Spotwelded; S_{max} = 390 MN/m^2 (57 ksi)			
115	106	108	122
120	125	113	126
126	134	125	140
128	135	130	143
129	155	134	154
Fusion welded; S_{max} = 570 MN/m^2 (82 ksi)			
61	68	94	56
93	92	152	64
129	115	184	76
143	134	256	85
	141	265	93

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER INTERMEDIATE EXPOSURES – Continued

(e) Ti-6Al-4V, annealed, exposed at 560 K (550° F); S_{mean} = 170 MN/m^2 (25 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 690 MN/m^2 (100 ksi)			
78	73	68	86
91	89	79	365
105	128	240	844
132	182	1 110	1 365
534	1119		1 440
K_T = 4; S_{max} = 280 MN/m^2 (40 ksi)			
33	33	36	36
35	38	36	37
41	40	47	39
50	45	48	42
51	1255	67	45
Spotwelded; S_{max} = 280 MN/m^2 (40 ksi)			
127	155	88	116
165	160	123	124
167	220	125	152
189	225	157	166
229	261	189	>10 000
Fusion welded; S_{max} = 520 MN/m^2 (75 ksi)			
53	43	41	43
56	51	44	49
83	53	67	58
89	107	82	60
133	228	>10 000	99

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE

AFTER INTERMEDIATE EXPOSURES – Continued

(f) Ti-4Al-3Mo-1V, aged, exposed at 560 K (550° F); S_{mean} = 170 MN/m^2 (25 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 480 MN/m^2 (70 ksi)			
42	70	120	129
119	202	141	>10 000
246	>10 000	194	>10 000
	>10 000	>10 000	>10 000
	>10 000	>10 000	>10 000
K_T = 4; S_{max} = 230 MN/m^2 (33 ksi)			
69	67	112	139
74	92	117	166
89	110	530	270
92	186	>10 000	>10 000
104	563	>10 000	>10 000
Spotwelded; S_{max} = 280 MN/m^2 (40 ksi)			
82	60	52	53
90	75	59	59
97	85	61	75
116	103	62	76
133	103	74	85
Fusion welded; S_{max} = 430 MN/m^2 (62 ksi)			
40	30	49	35
41	34	58	46
43	56	9 785	47
50	65	>10 000	66
52	75	>10 000	2 389

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE

AFTER INTERMEDIATE EXPOSURES – Continued

(g) Ti-8Al-1Mo-1V, annealed exposed at 560 K (550° F); S_{mean} = 170 MN/m^2 (25 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 620 MN/m^2 (90 ksi)			
49	59	86	167
78	60	155	293
90	94	1268	4 532
92	151	4401	9 887
361	216		>10 000
K_T = 4; S_{max} = 280 MN/m^2 (40 ksi)			
44	33	35	46
46	40	35	47
48	59	56	51
48	493	60	52
56	59	43	57
Spotwelded; S_{max} =260 MN/m^2 (38 ksi)			
121	139	140	140
141	153	168	284
186	204	419	336
290	208	503	399
575	217	559	
Fusion welded; S_{max} = 520 MN/m^2 (75 ksi)			
42	47	43	39
67	74	46	63
89	115	53	69
156	116	102	90
323	156	494	300

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE

AFTER INTERMEDIATE EXPOSURES – Continued

(h) Ti-8Al-1Mo-1V, duplex annealed, exposed at 560 K (550° F); S_{mean} = 170 MN/m^2 (25 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 660 MN/m^2 (95 ksi)			
107	78	100	110
136	93	109	172
140	116	158	178
140	168	178	202
	554		3272
K_T = 4; S_{max} = 280 MN/m^2 (40 ksi)			
32	50	42	39
41	50	44	50
47	53	51	50
51	55	51	51
61	57	55	54
Spotwelded; S_{max} = 280 MN/m^2 (40 ksi)			
157	135	125	134
173	141	158	145
180	154	163	159
188	173	191	180
198	205		189
Fusion welded; S_{max} = 520 MN/m^2 (75 ksi)			
39	50	51	42
50	60	65	53
53	77	66	64
65	187	105	715
78		1033	921
			1612

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE AFTER INTERMEDIATE EXPOSURES – Continued

(i) RR 58, clad, exposed at 390 K (250° F); S_{mean} = 90 MN/m^2 (13 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 240 MN/m^2 (35 ksi)			
58	46	65	65
67	66	75	71
68	71	84	79
72	73	86	80
72	75	94	81
79	75	122	89
K_T = 4; S_{max} = 140 MN/m^2 (20 ksi)			
30	36	43	38
36	41	46	42
40	47	47	46
50	51	47	48
53	54	49	56
57	58	53	82

(j) RR 58, clad, exposed at 420 K (300° F); S_{mean} = 90 MN/m^2 (13 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
K_T = 1; S_{max} = 240 MN/m^2 (35 ksi)			
66	46	67	
70	56	75	
71	62	76	
71	64	93	
74	73	102	
75	80	113	
K_T = 4; S_{max} = 140 MN/m^2 (20 ksi)			
39	23	35	
41	46	36	
45	50	62	
48	51	64	
69	59	64	
70	69	87	

TABLE IV.- RESULTS OF FATIGUE TESTS AT ROOM TEMPERATURE

AFTER INTERMEDIATE EXPOSURES – Concluded

(k) 2024-T81, clad, exposed at 390 K (250° F); $S_{mean} = 90$ MN/m^2 (13 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
$K_T = 1$; $S_{max} = 240$ MN/m^2 (35 ksi)			
51	58	58	61
63	59	67	67
63	82	79	70
66	90	80	79
67	121	95	
$K_T = 4$; $S_{max} = 140$ MN/m^2 (20 ksi)			
35	38	43	42
37	41	44	43
37	41	47	43
38	42	50	47
40	51	52	47

(l) 2024-T81, clad, exposed at 420 K (300° F); $S_{mean} = 90$ MN/m^2 (13 ksi)

Fatigue lives in kilocycles after exposures of –			
2200 hours	4400 hours	8800 hours	17 500 hours
$K_T = 1$; $S_{max} = 240$ MN/m^2 (35 ksi)			
52	55	57	53
62	59	62	56
63	76	65	68
66	78	86	79
75	87	87	83
$K_T = 4$; $S_{max} = 140$ MN/m^2 (20 ksi)			
32	44	41	41
32	47	42	42
38	48	52	44
43	52	57	51
43	53		56

TABLE V.- EFFECT OF EXPOSURE TO 560 K (550° F) FOR 26 300 HOURS ON STATIC STRENGTHS[1] OF FATIGUE SPECIMENS

[Two tests per value]

Material	$K_T = 1$					Spotwelded				
	Strength before exposure		Strength after exposure		Ratio	Strength before exposure		Strength after exposure		Ratio
	ksi	MN/m^2	ksi	MN/m^2	(2)	ksi	MN/m^2	ksi	MN/m^2	(2)
PH 15-7 Mo	206	1420	---	----	---	173	1190	---	----	---
AM 350 CRT	195	1350	205	1410	1.05	184	1270	180	1240	0.98
AM 350 DA	207	1430	193	1330	.93	169	1170	186	1280	1.10
AISI 301	206	1420	227	1570	1.10	186	1280	171	1180	.92
Ti-6Al-4V	152	1050	163	1120	1.07	[3]148	[3]1020	161	1110	1.09
Ti-4Al-3Mo-1V	141	973	142	979	1.01	[4]141	[4]973	144	993	1.02
Ti-8Al-1Mo-1V,An	156	1080	158	1090	1.01	151	1040	153	1050	1.01
Ti-8Al-1Mo-1V,DAn	154	1060	[5]158	[5]1090	[5]1.03	---	----	---	----	---
	$K_T = 4$					Fusion welded				
PH 15-7 Mo	214	1480	205	1410	0.96	[6]139	[6]960	[6]160	[6]1100	[6]1.15
	---	----	---	----	---	[7]208	[7]1440	[7]212	[7]1460	[7]1.02
AM 350 CRT	201	1390	201	1390	1.00	139	960	132	910	.95
AM 350 DA	218	1500	196	1350	.90	[6]125	[6]862	[6]135	[6]931	[6]1.08
	---	----	---	----	---	[7]187	[7]1290	[7]191	[7]1320	[7]1.02
AISI 301	198	1370	210	1450	1.06	130	896	126	869	.97
Ti-6Al-4V	163	1120	174	1200	1.07	160	1100	165	1140	1.03
Ti-4Al-3Mo-1V	141	973	140	965	.99	146	1010	147	1010	1.01
Ti-8Al-1Mo-1V,An	167	1150	164	1130	.98	159	1100	159	1100	1.00
Ti-8Al-1Mo-1V,DAn	---	----	[5]164	[5]1130	---	158	1090	163	1120	1.03

[1]Strengths based on net cross-sectional areas for unnotched, notched, and fusion-welded specimens and on cross-sectional area of tang for spotwelded specimens.

[2]Strength after exposure divided by strength before exposure.

[3]Three tests. All failed away from welds.

[4]One specimen failed away from welds.

[5]After 32 100 hours.

[6]Fusion welded after heat treatment.

[7]Fusion welded before heat treatment.

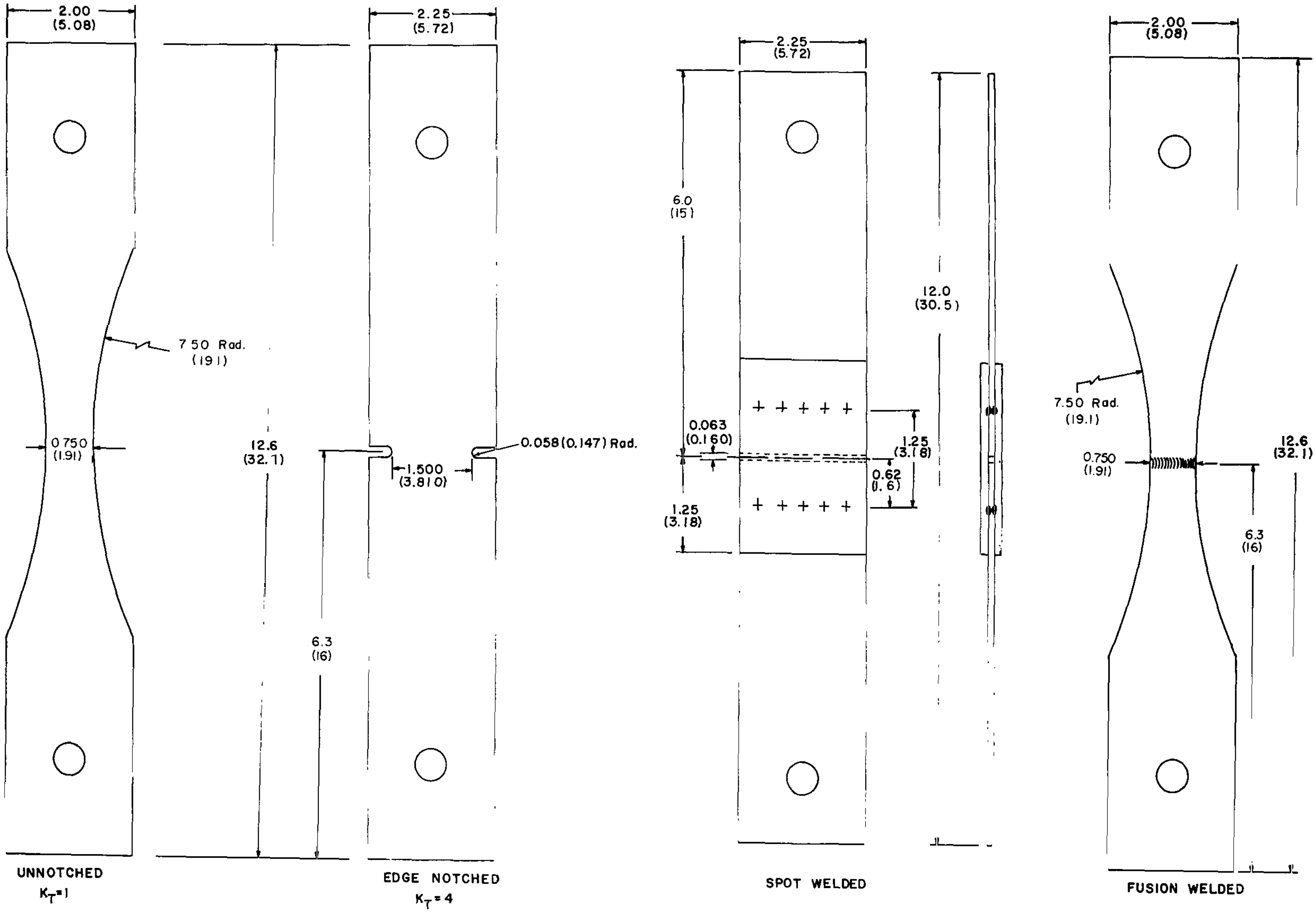
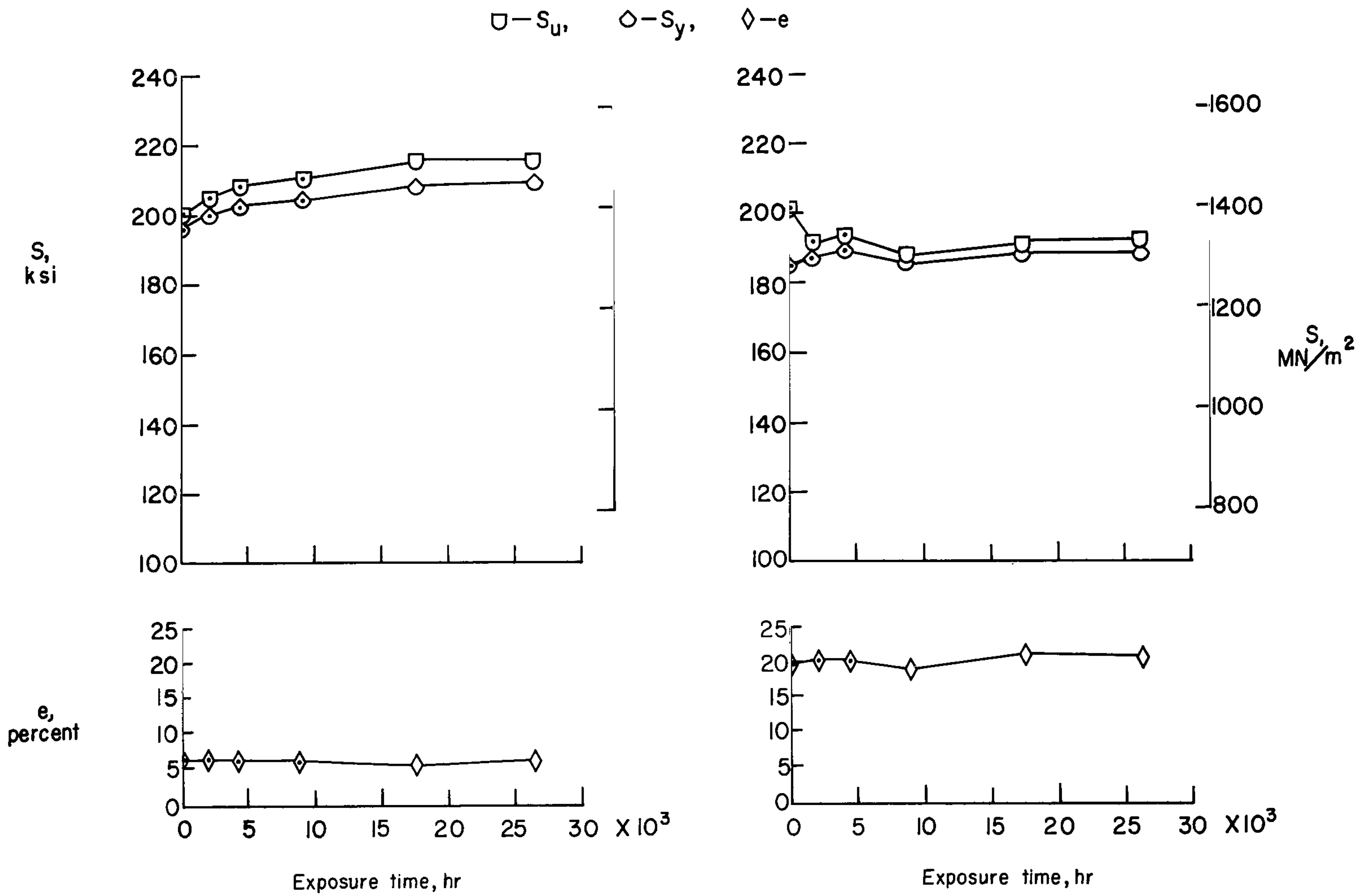


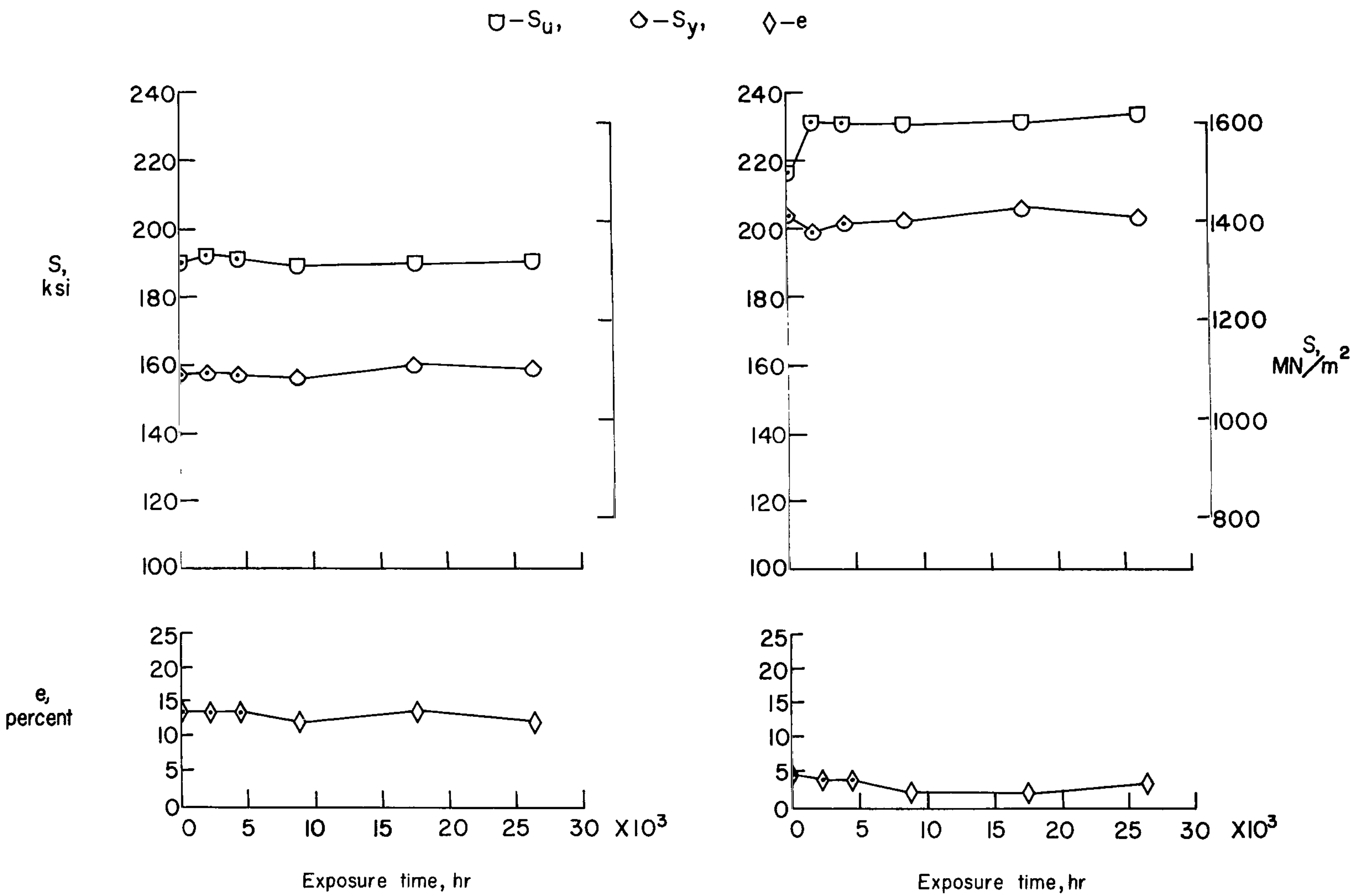
Figure 1.- Fatigue specimens. All dimensions are in inches (centimeters).



(a) PH 15-7 Mo TH 1050; exposed at 560 K (550° F).

(b) AM 350, 20-percent CRT; exposed at 560 K (550° F).

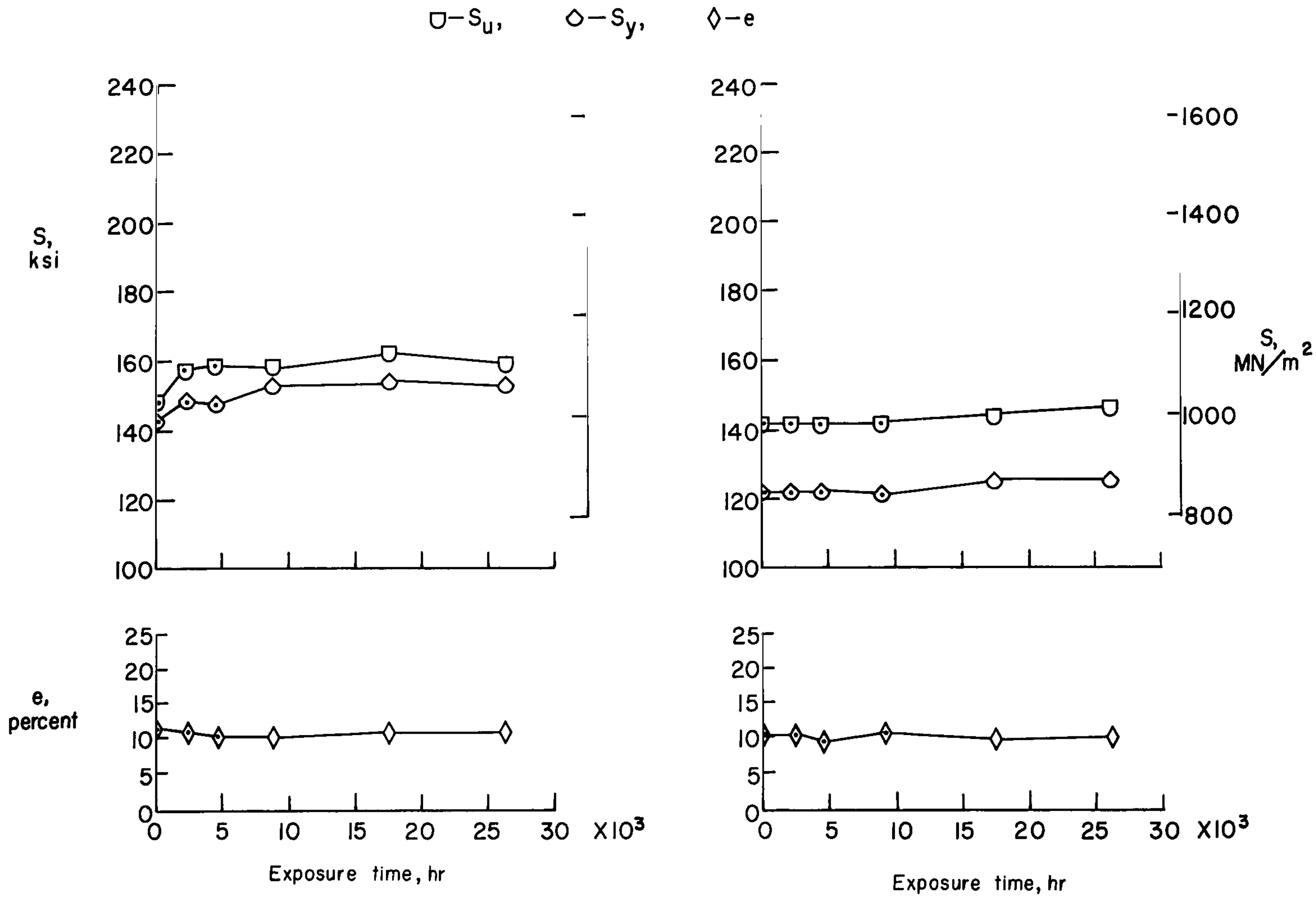
Figure 2.- Effects of exposure to elevated temperature on average room-temperature tensile properties. Dot in symbol indicates data from reference 1.



(c) AM 350, double aged; exposed at 560 K (550° F).

(d) AISI 301, 50-percent CR; exposed at 560 K (550° F).

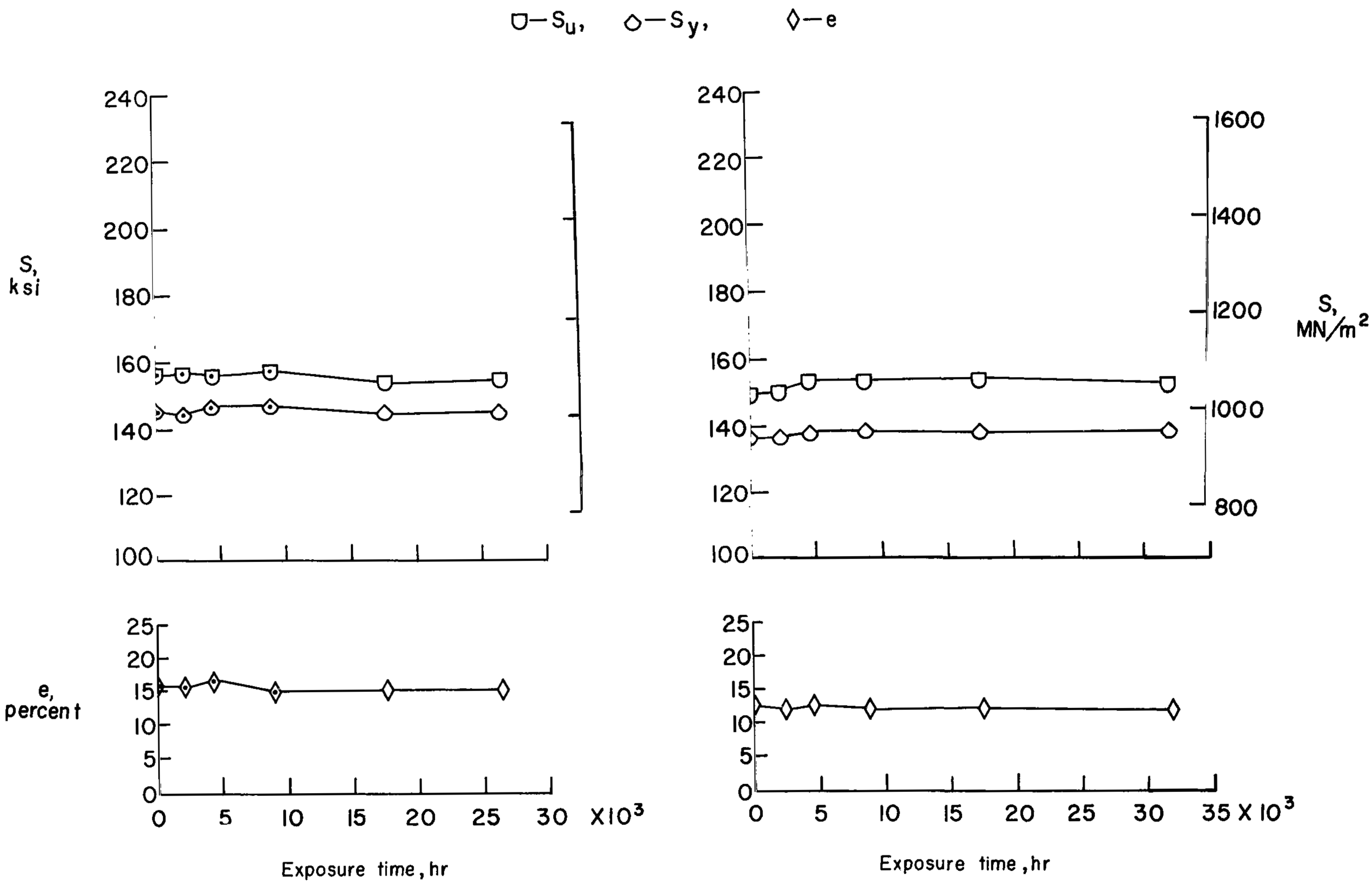
Figure 2.- Continued.



(e) Ti-6Al-4V, annealed; exposed at 560 K (550° F).

(f) Ti-4Al-3Mo-1V, STA; exposed at 560 K (550° F).

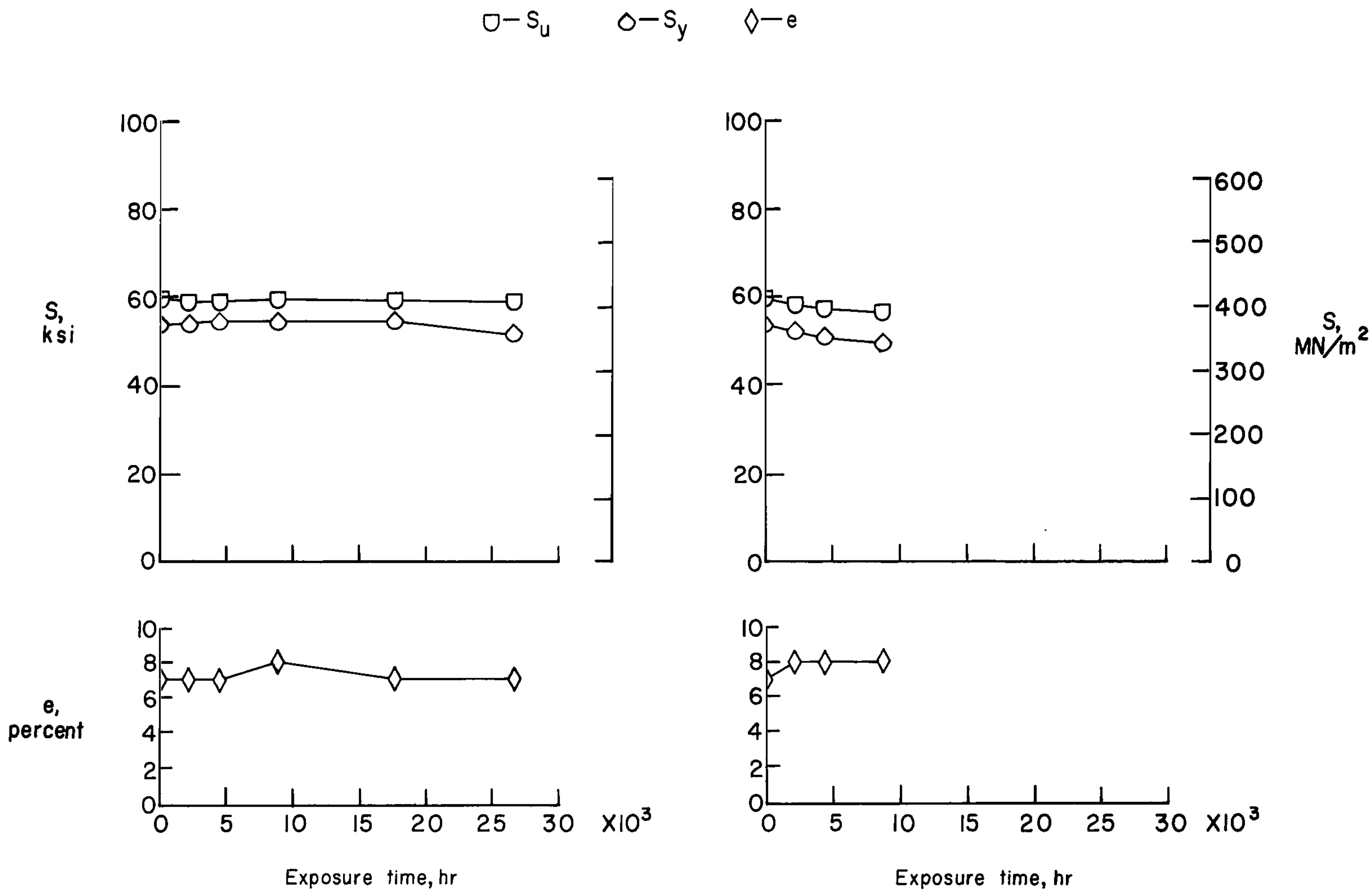
Figure 2.- Continued.



(g) Ti-8Al-1Mo-1V, annealed; exposed at 560 K (550° F).

(h) Ti-8Al-1Mo-1V, duplex annealed; exposed at 560 K (550° F).

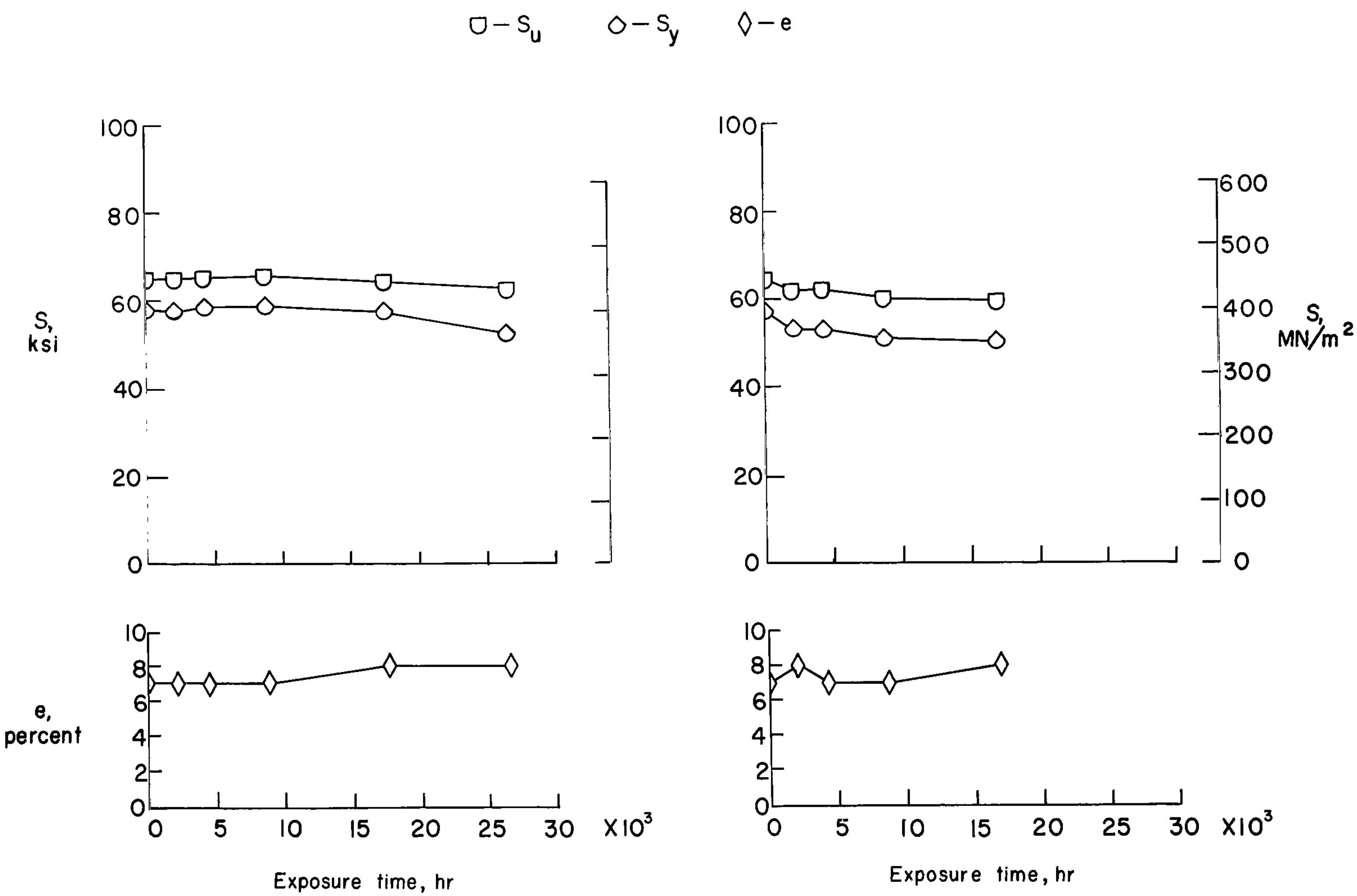
Figure 2.- Continued.



(i) RR 58, clad; exposed at 390 K (250° F).

(j) RR 58, clad; exposed at 420 K (300° F).

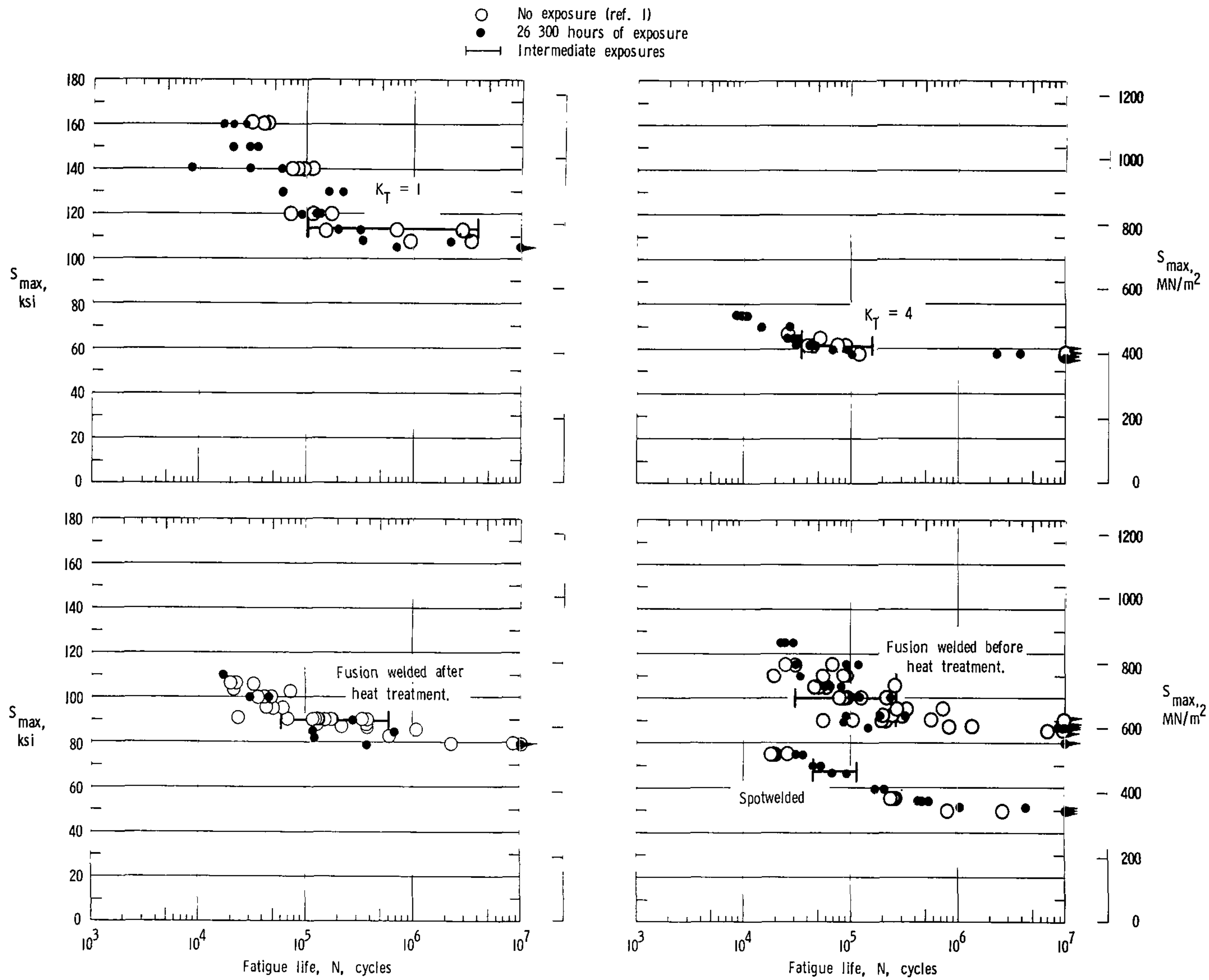
Figure 2.- Continued.



(k) 2024-T81, clad; exposed at 390 K (250° F).

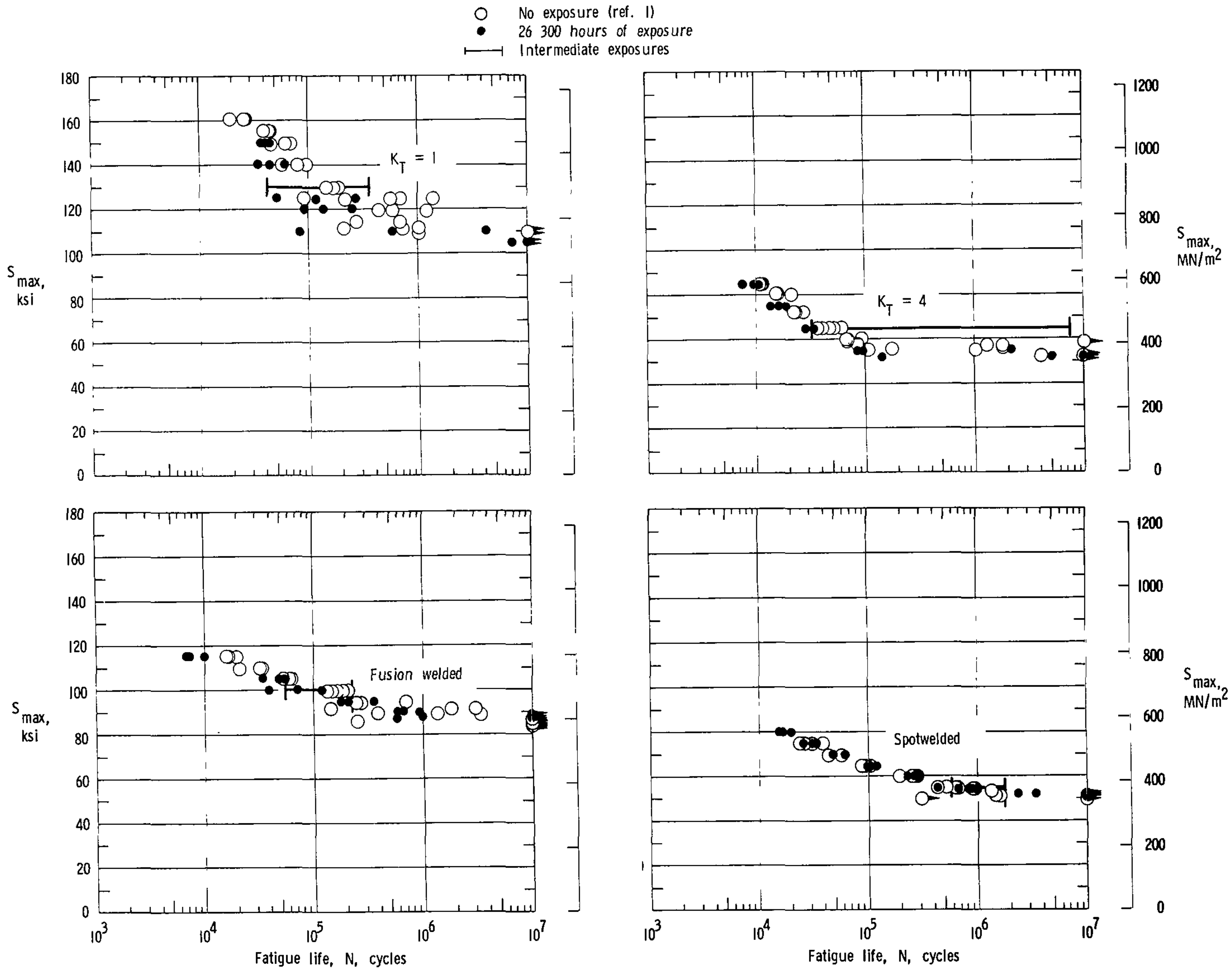
(l) 2024-T81, clad; exposed at 420 K (300° F).

Figure 2.- Concluded.



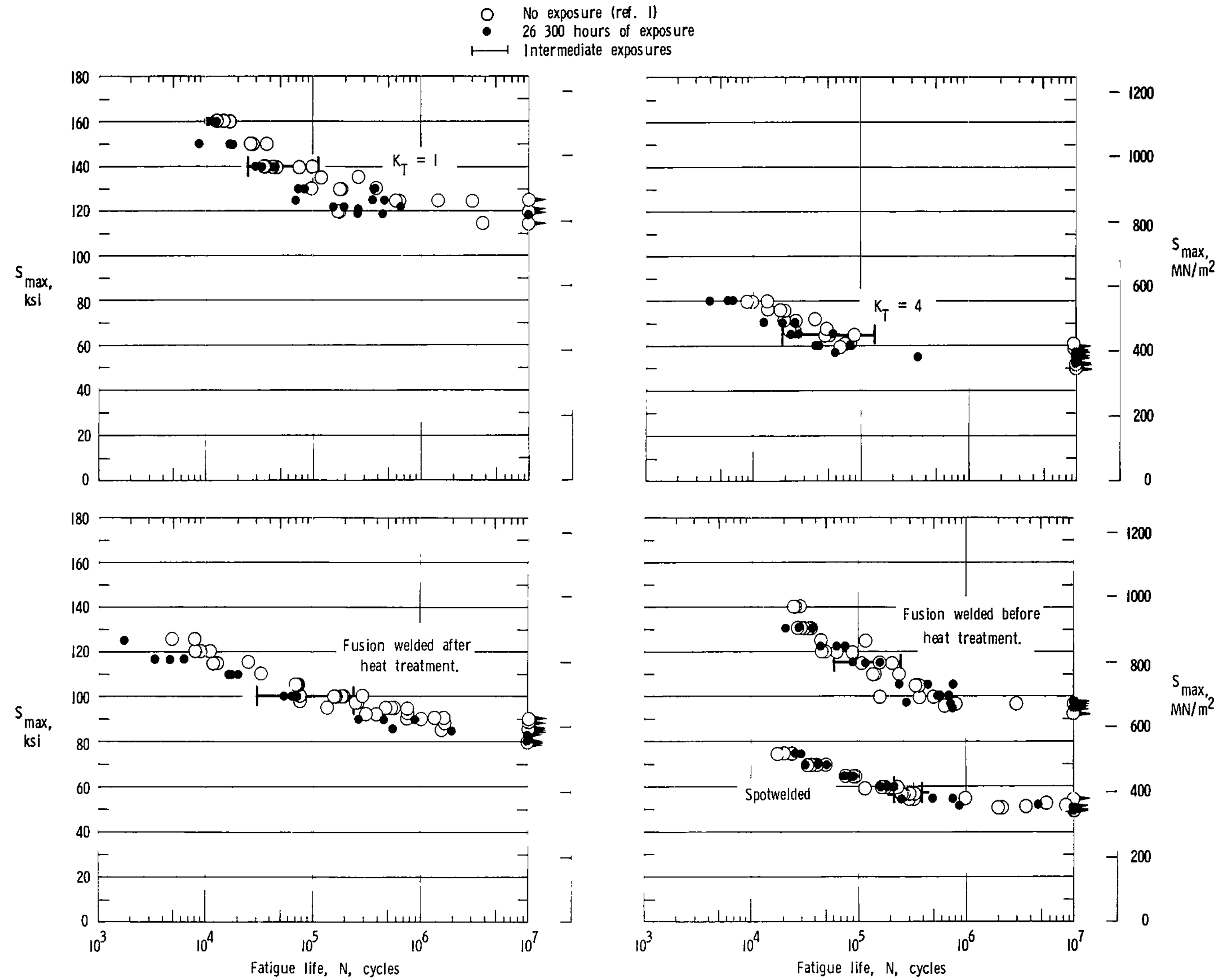
(a) PH 15-7 Mo, TH 1050; exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Results of room-temperature axial-load fatigue tests before and after elevated-temperature exposure.



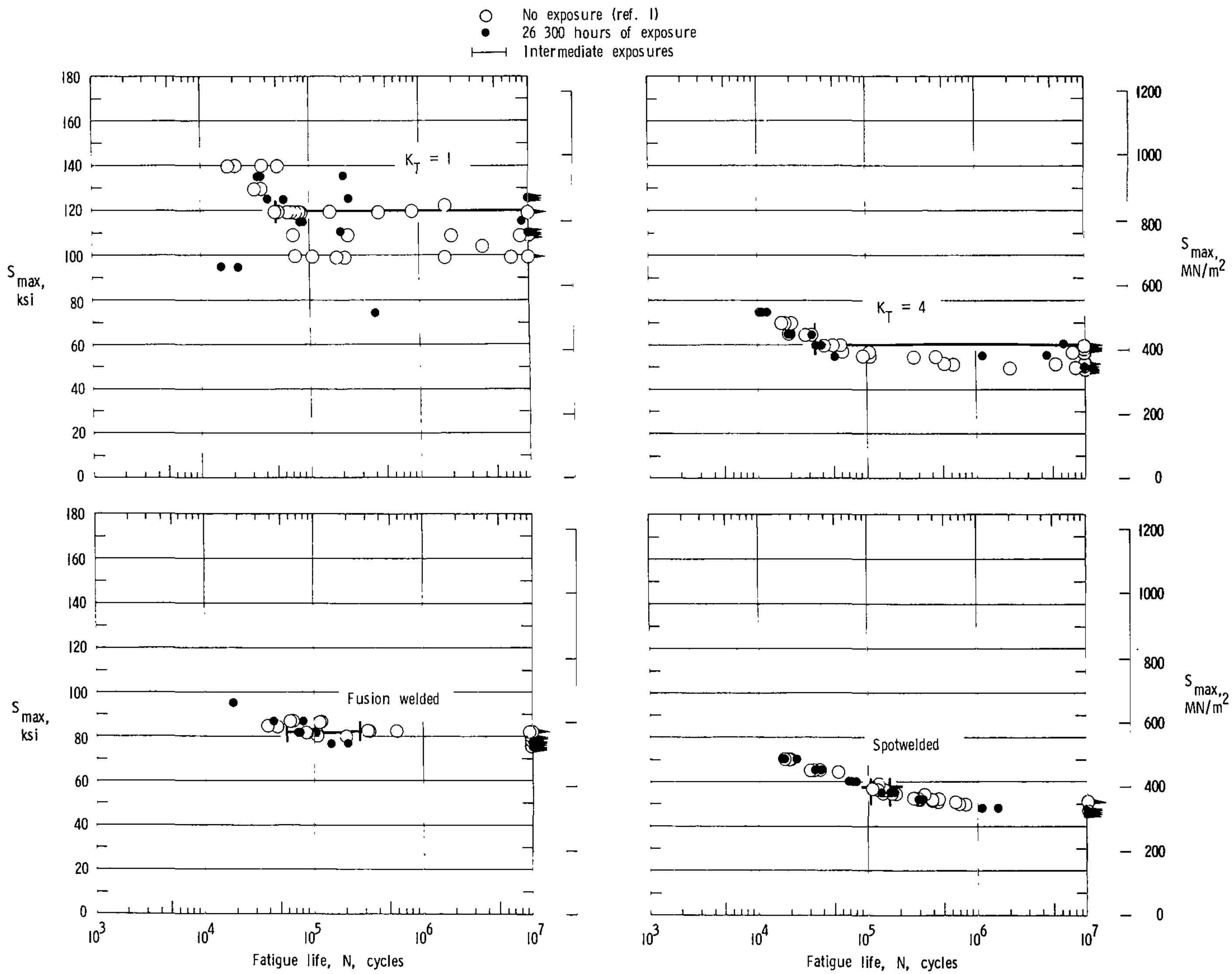
(b) AM 350, 20-percent CRT; exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Continued.



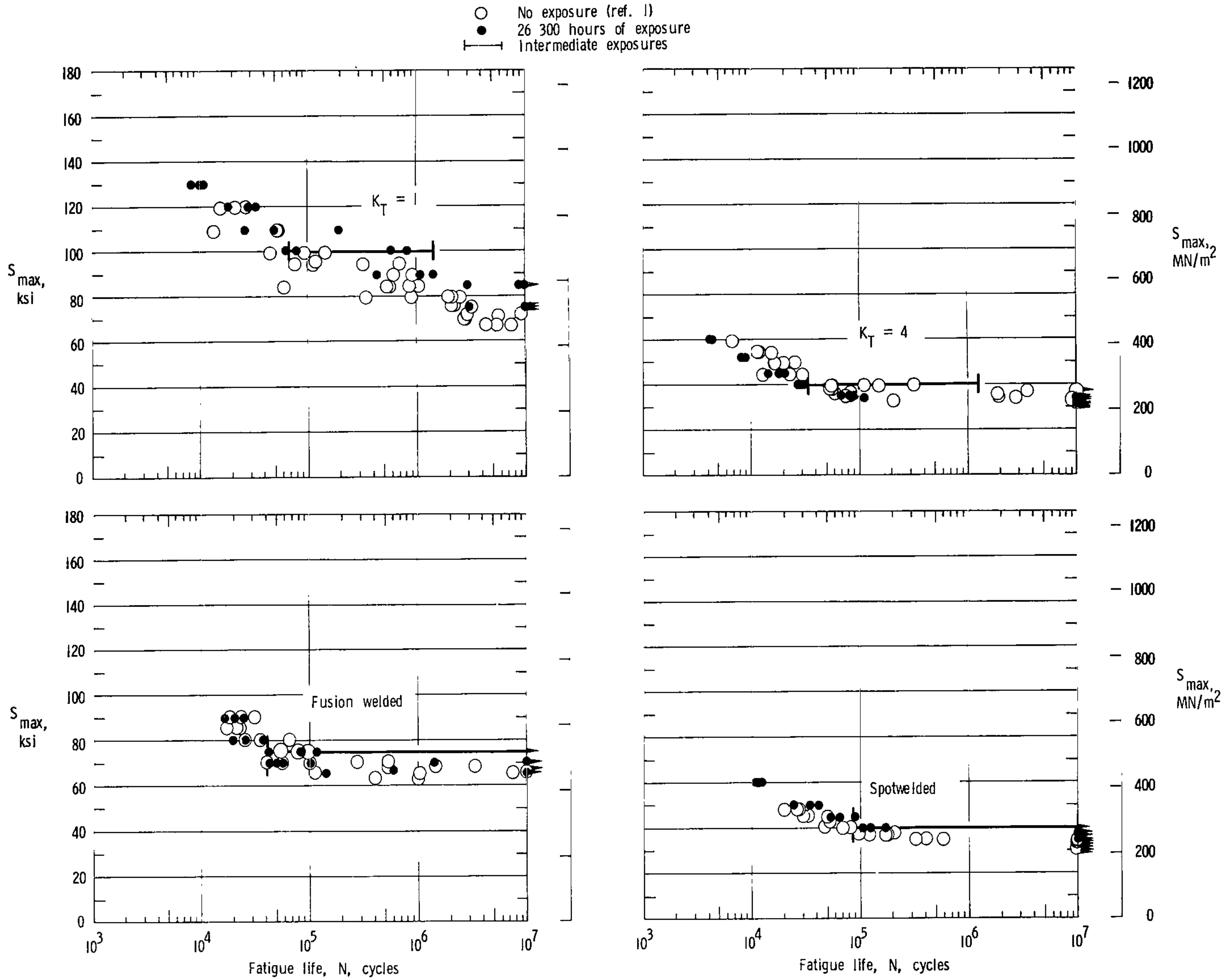
(c) AM 350, double aged; exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Continued.



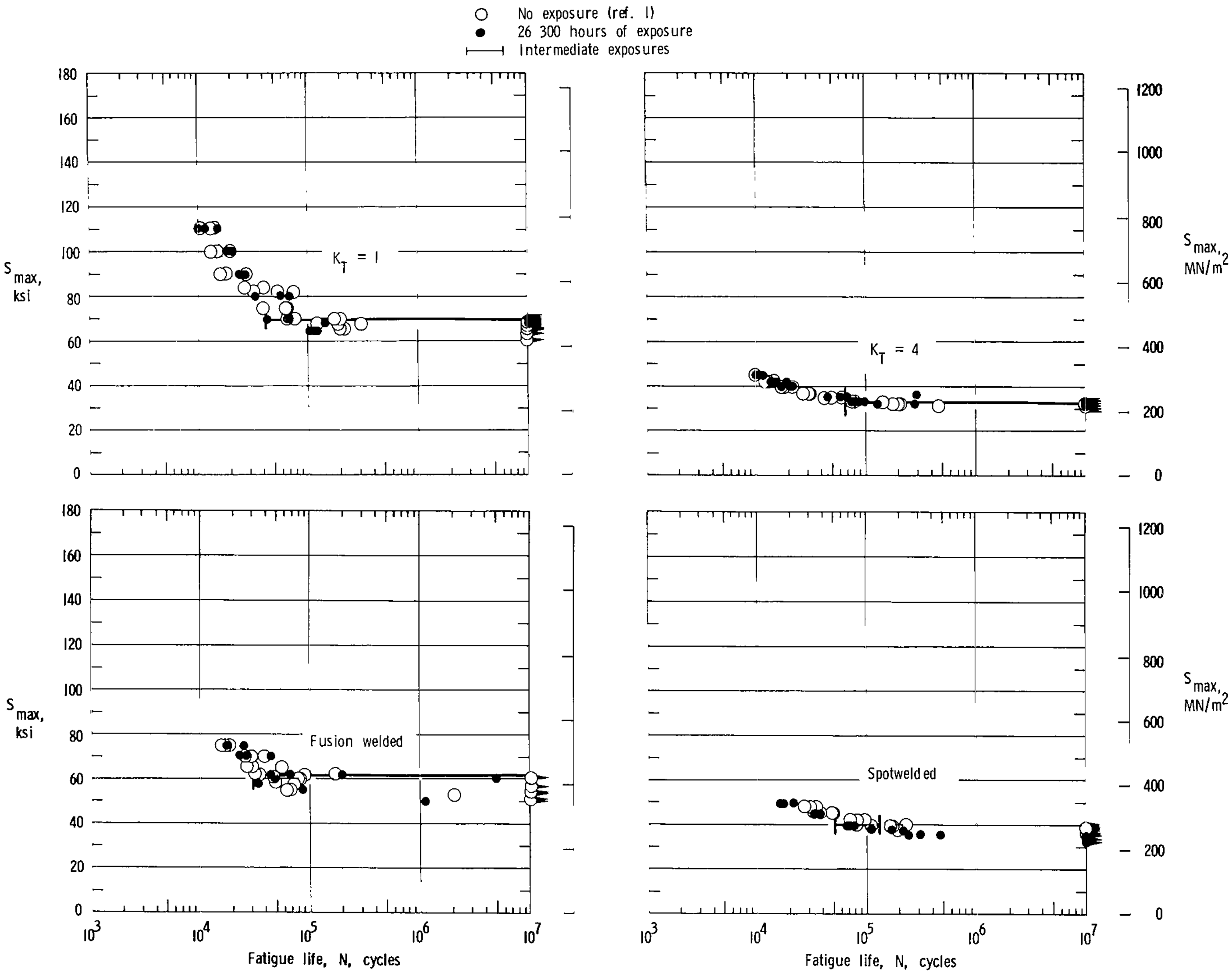
(d) AISI 301, 50-percent CR; exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Continued.



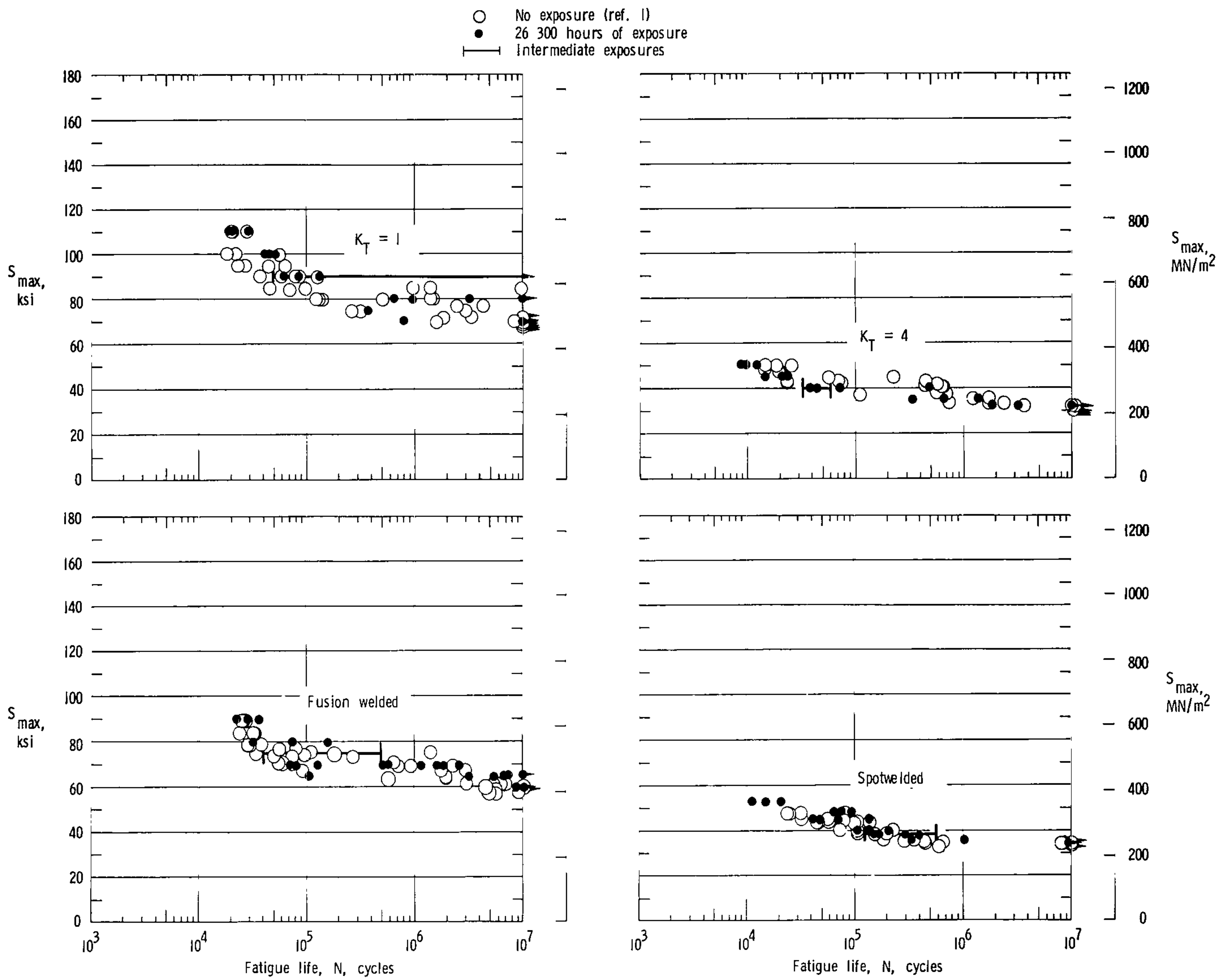
(e) Ti-6Al-4V, annealed; exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Continued.



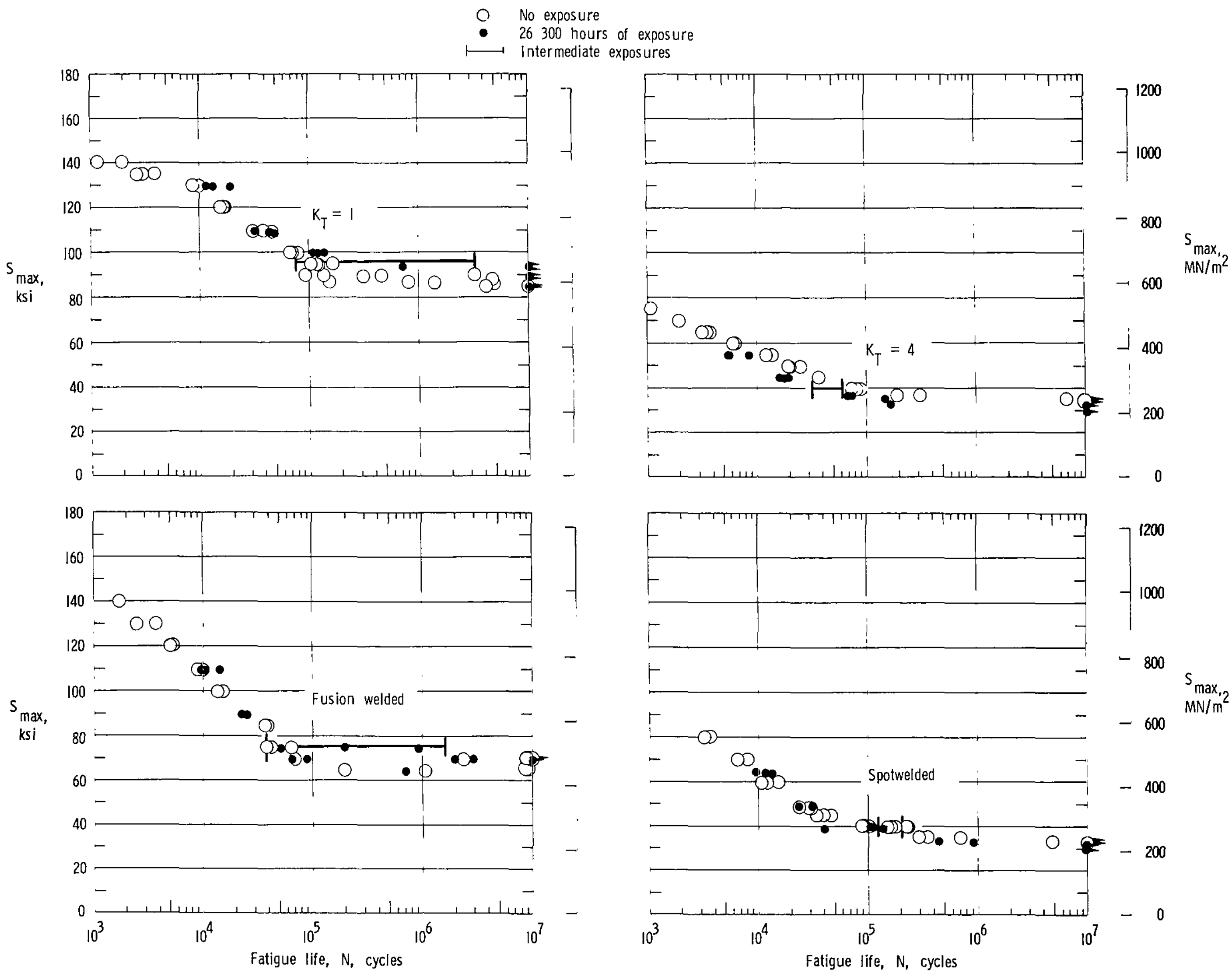
(f) Ti-4Al-3Mo-1V, STA, exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Continued.



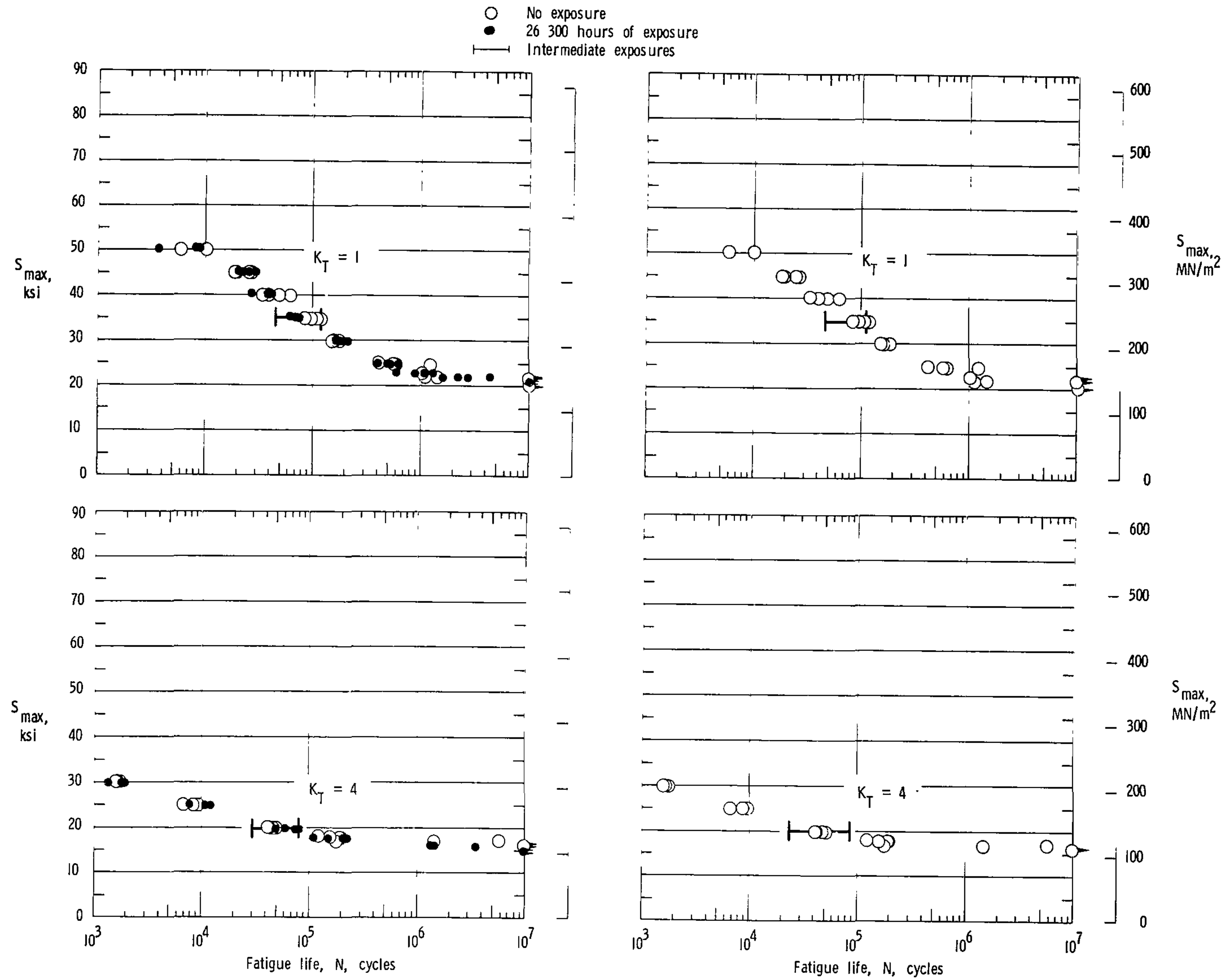
(g) Ti-8Al-1Mo-1V, annealed; exposed for 26 300 hours at 560 K (550° F).

Figure 3.- Continued.



(h) Ti-8Al-1Mo-1V, duplex annealed; exposed for 32 100 hours at 560 K (550° F).

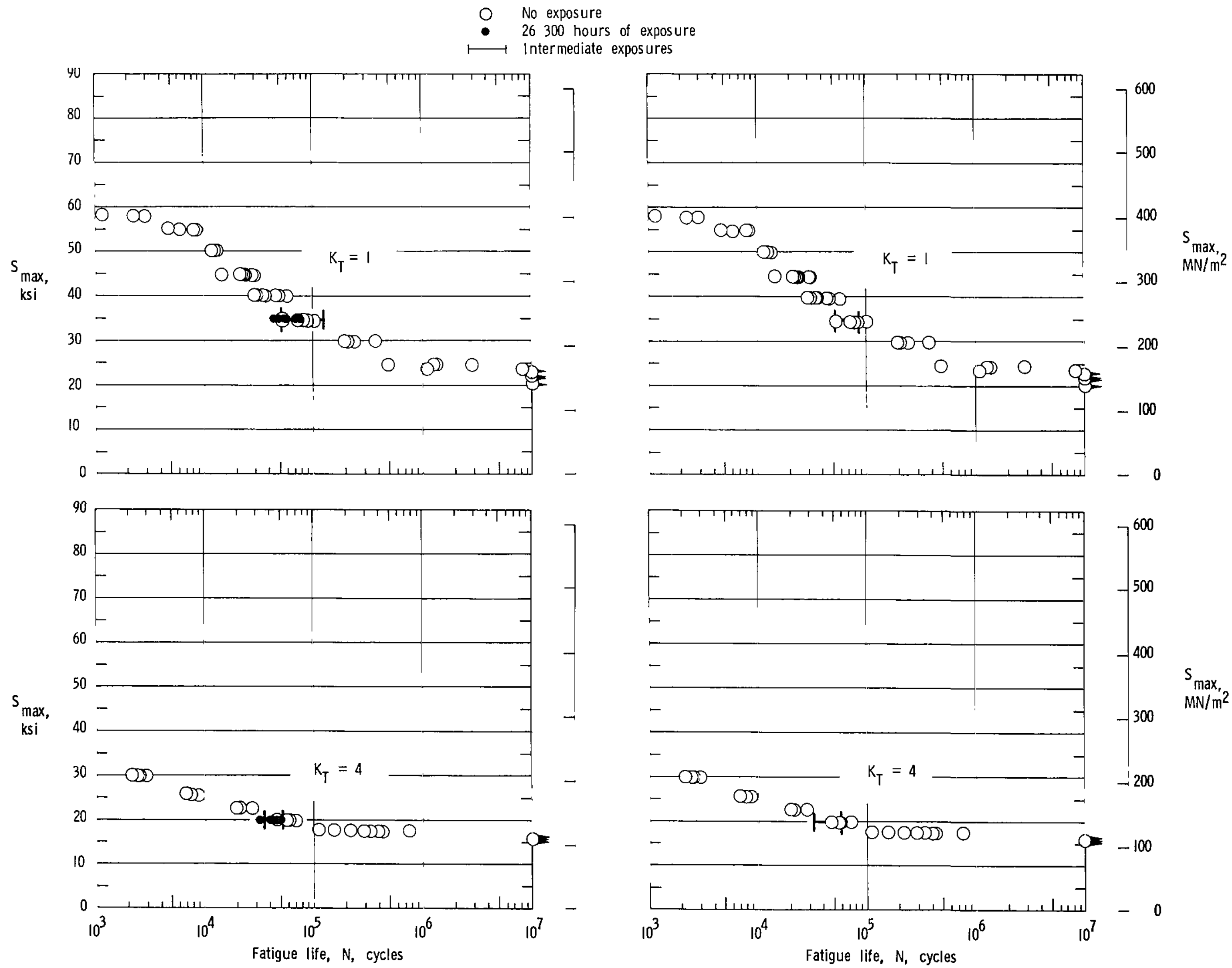
Figure 3.- Continued.



(i) RR 58, clad; exposed for 26 300 hours at 390 K (250° F).

(j) RR 58, clad; exposed for 8800 hours at 420 K (300° F).

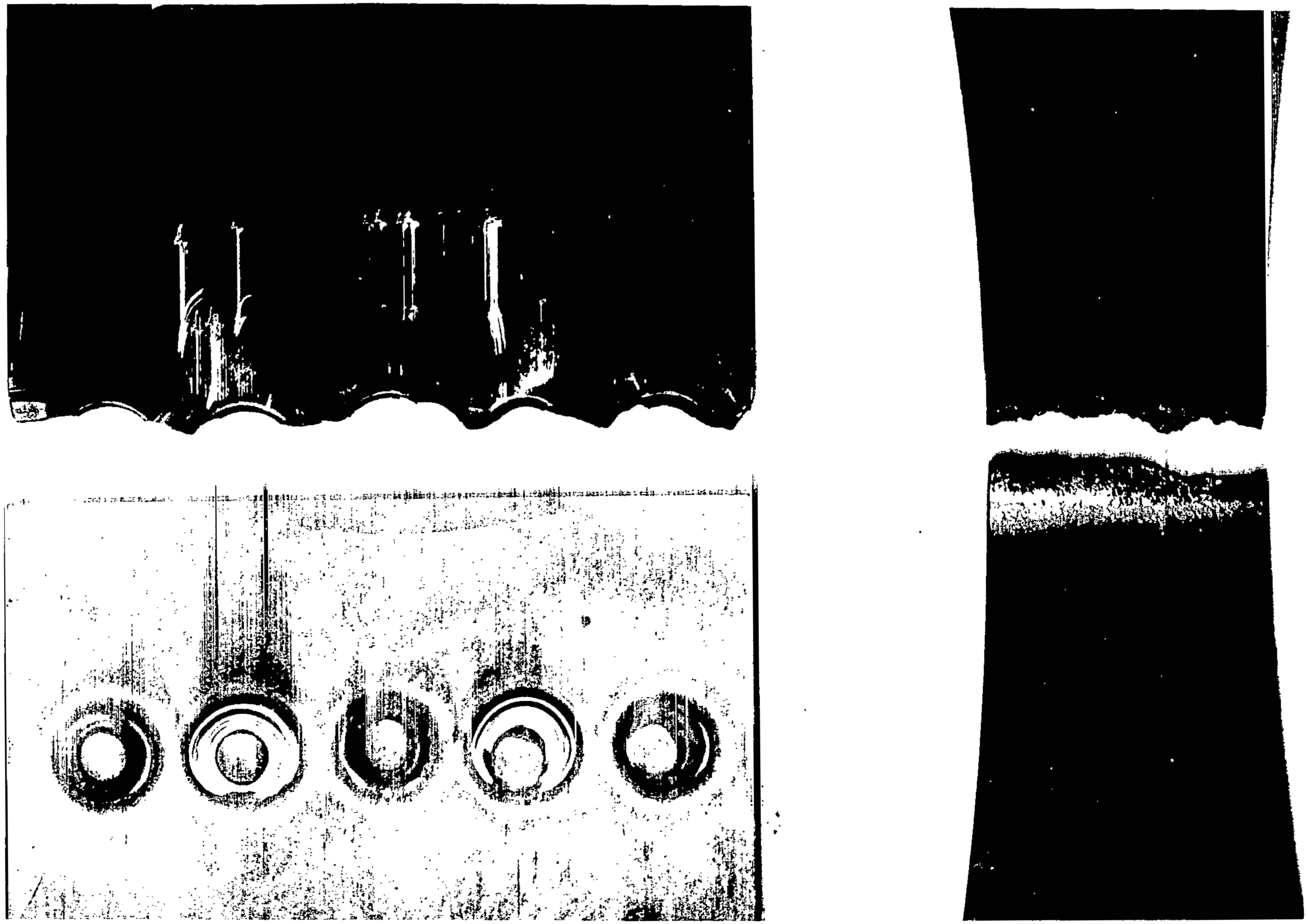
Figure 3.- Continued.



(k) 2024-T81, clad; exposed for 26 300 hours at 390 K (250° F).

(l) 2024-T81, clad; exposed for 17 500 hours at 420 K (300° F).

Figure 3.- Concluded.



L-70-5543

Figure 4.- Typical fatigue failures in spotwelded and fusion-welded specimens. Ti-8Al-1Mo-1V, duplex annealed. Magnification ×2.

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